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ABSTRACT

This competency-based energy conservation in agriculture curriculum for grades 11 and 12 is organized into seven modules. Intended for use for individualized or group instruction, the lessons should fit into existing units in courses of study rather than be presented as a single comprehensive energy conservation unit. Each module is based on from one to five competencies. For each one a student competency sheet is provided with the following information: module number and title, competency statement, an introduction, a list of needed resources and equipment, a list of learning activities, and a list of evaluation activities. Where appropriate, referance materials (reprints of articles, circulars, and bulletins), lecture notes, and transparency masters are provided to enable the students to complete the learning activities. Module topics are an introduction to energy conservation in agricultural and energy conservation in livestock and poultry production, farm lighting, tractor and farm engine operation, farm truck and pickup usage, crops production, and greenhouse operations. (Sources of additional reference materials needed to complete lessons are cited.) (YLB)

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Competency Based Curriculum
for
Energy Conservation
in Agriculture

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December 1982

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PREFACE

It is with great pleasure that we bring you another West Virginia competency based education (CBE) curriculum. This competency based Energy Conservation in Agriculture curriculum was developed under contract for West Virginia. The effort was coordinated by staff of the West Virginia Department of Education, Bureau of Vocational, Technical and Adult Education.

This document is organized into seven modules. The modules and competencies are listed in the Contents.

This competency based Energy Conservation in Agriculture curriculum was disseminated to West Virginia agriculture instructors at inservices conducted in the Spring of 1983. Additional copies of this curriculum are available from the:

Vocational Curriculum Laboratory
Cedar Lakes Conference Center
Ripley, West Virginia 25271
Telephone: (304) 372-8673 or
Toll-free 1-800-642-2670 (in-state)

We trust this material will be of assistance in your program. Any suggestions you may have for improving this curriculum may be sent to our Vocational Curriculum Laboratory. Through this feedback we plan to continually update and revise our materials.

VOCATIONAL, TECHNICAL AND ADULT EDUCATION

Clarence E. Burdette
Assistant State Superintendent of Schools

FOREWORD

Can you believe it? More than six billion gallons of gasoline and diesel fuel used in the United States each year in farming/ranching operations!. . . To say nothing of the LP gas, natural gas, fuel oil and electricity consumed in producing agricultural products. Surely we can produce as much or more food and fiber with less fuel.

That's what this teaching plan is all about--to develop attitudes and competencies which will allow our future farmers and greenhouse growers to produce more with less, to practice energy efficiency.

Lessons are designed for 11th and 12th grade students. They can be used for individualized or group instruction. They should fit into existing units in courses of study rather than presented as a single comprehensive energy conservation unit. And they can be adapted to accomodate your favorite teaching styles and needs of your own community and students.

I hope you find them useful.

Layle D. Lawrence
Professor, Agricultural Education
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Contributions of the Following individuals are recognized:

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Cameron High School

Charles Larew, Vo-Ag Teacher
Monroe County Vo-Tech

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REFERENCE MATERIALS

Most reference materials needed for completing lessons in Energy Conservation in Agriculture can be found following each Student Competency Sheet. Those which are not included in the publication are available from the following sources:

Agricultural Engineering Extension
118 Agricultural Sciences Annex
West Virginia University
Morgantown, WV 26506
(ph. 292-5539)

Slide Set

"Fuel and Farm Machinery" (80 slides, script, cassette tape)

Film

"Sun Power for Farms" (14 minute 16mm film, color and sound) Includes discussion of solar heated greenhouses, farm buildings and grain dryers.

Deere & Company
Distribution Service Center - Dept. S/P
1400 - 3rd Avenue
Moline, Illinois 61265

FOS-30B	Engines
FMO-101B	Tractors
FOS-56B	Mowing and Spraying
FMO-121B	Planting
FOS-58B	Fuels, Lubricants & Cooling
FMO-131B	Crop Chemicals

AAVIM
120 Engineering Center
Athens, Georgia 30602

Selecting and Storing Fuels and Lubricants

Chevron Chemical Company
Ortho Division
200 Bush Street
San Francisco, California 94120

No-Tillage Farming

Venard Films, Ltd.
Box 1332
Peoria, Illinois 61654

Film: "Pesticides: Fundamentals of Proper Application" (13 minutes) Essentials of sprayer equipment, including adjustments for proper spray application.

Other Materials

Operators or Technical Manuals for specific tractors, engines and machines involved in exercises. Contact owners, dealers or manufacturers for copies.

Check for availability of additional slides, films, and other materials periodically at the WV Vocational Curriculum Laboratory at Cedar Lakes. Toll free phone 1-800-642-2670.

STUDENT COMPETENCY SHEET

Module 1: Introduction to Energy Conservation in Agriculture

Competency: Analyze options in energy conservation

Introduction:

How many choices have you made today? Probably hundreds. From early morning (Shall I get out of bed or sleep in?), throughout the day (Shall I go to school or skip?) Shall I throw this paper wad?), and into the night (Shall I watch TV or study?), choices must be made. Some are made as a matter of habit, others require a great deal of thought. Your happiness and success depends on how wisely those choices are made.

This lesson deals with coices available to you in energy conservation. Everyone knows that money and resources can be saved by using less energy. But to actually use less energy, you must (a) be aware of various methods of saving energy, (b) analyze advantages and disadvantages of each method, and (c) make decisions (choices) you feel will be most beneficial to you.

Resources and Equipment:

"The Face of the Future," an article in the VocEd Journal, January/February, 1982.

Instructor lecture notes, transparencies

Overhead projector

Learning Activities:

1. Read "The Face of the Future," and other articles or information you can find relating to energy conservation in agriculture. For each resource write: (a) the title and source, (b) what you think of the information, and (c) how it relates to the competency.
2. Attend a lecture by your teacher on energy conservation options available in agriculture. Take notes.
3. Discuss, with your classmates and teacher, examples and implications of energy conservation options available in agriculture.
4. Take a walking tour of your farm or one in your community and very carefully look for and list the ways that energy is consumed.
5. As a sort of pretest, suggest in writing ways of conserving energy for each item on your list from Learning Activity #4.

Evaluation:

1. Turn in your resource information from Learning Activity #1. Try to find at least two resources in addition to the one listed.
2. Turn in your list of energy consumption items from Learning Activity #4 and your conservation suggestions from Learning Activity #5. Your instructor will review it and return it to you for use at a later date.
3. Identify the two options which you feel have the greatest potential for energy savings in your community and explain why those two were selected.
4. Be able to name two direct and three indirect types of energy consumption in agriculture.

The Face of the Future
AGRICULTURE

by David A. Hill

The farmer of today is the most efficient producer in the world. The farmer of tomorrow will be even more efficient, harnessing the wonders and powers of science and advanced technology to produce more with fewer hours of labor. Farms will be transformed by advanced mechanization, telecommunications, energy conservation and genetic plant research.

Vast changes in farm machinery are just around the corner. The short-term goals are to enhance energy efficiency and safety. Larger yet lighter equipment with more horsepower will reduce fuel consumption. Alternate fuel sources will reduce energy costs. Equipment will be self-steering and self-adjusting and will be operated with less fatigue and greater safety.

Further changes will produce farm equipment similar to aircraft with automatic pilots. Mini-computers will allow the farmer to "punch in" his day's activities and let the machine do most of the work. Farmers can look ahead to the day when all work on the farm will be conducted by automatic machinery, controlled by computer programs and supervised by television scanners atop monitor towers.

The farmer will use an in-home computer to program operational needs and costs. Financial data stored in the computer will be retrieved easily for review and update. The farm computer will bring market prices, minute by minute, directly to the farmer, permitting the most cost-efficient purchases of seed, fertilizer, parts, and so on.

The computer will also permit the farmer to monitor that traditionally unknown factor, nature. In the future, satellite discs on the farm will receive signals from orbiting spacecraft that transmit weather conditions, allowing the farmer to reduce weather risks. Other space technology will feed information to computers to identify and measure land use, assess crops and predict yields, detect plant disease and insect infestation, and determine the suitability of soil for particular crops.

Agricultural research will lead to practical ways for the farmer of tomorrow to trap and store energy from natural resources right on the farm. Some farmers are already using farm by-products to produce fuel. Tomorrow, many will rely on solar and wind collection to generate energy and reduce the use of fossil fuels.

The farmer of tomorrow will be more concerned than ever with the conservation of soil and water. To reduce soil compaction, equipment of the future will be lighter. Researchers are even looking into the use of air vehicles that can hover above the ground. Soil erosion will be reduced by conservation tillage and other advances will allow

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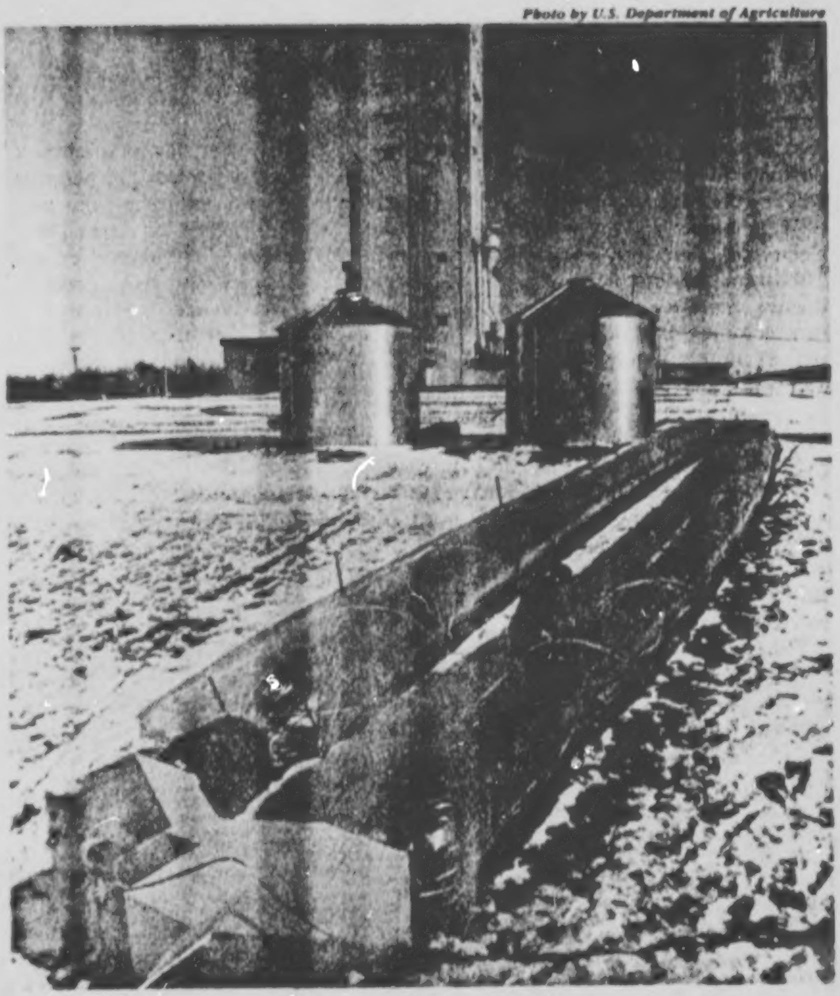
Photo by U.S. Department of Agriculture



In mid-winter, a farmer inspects his air-inflated solar collector, one of the ways tomorrow's agriculturists will trap and store energy on their own farms.

AGRICULTURE

Continued from page 35

more efficient use of less-than-prime land. The dwindling supply of water will bring about improvement in distribution systems, irrigation scheduling and the recycling of waste water.

New technologies using hydroponics will revolutionize farming. Hydroponics is the science of growing plants without soil, using recycled and nutrient-laden water and a climate-controlled greenhouse. It makes it possible to grow food where there is little or no rainfall, or even in urban areas. Some commercial hydroponics operations are already providing fresh vegetables for local city markets.

There are also new crops ahead for the American farmer. Major work in the next decade will concentrate on gene splicing and plant genetic research. More hybrids will come first, but farmers will also see the introduction of entirely new crops. Scientists have already combined the sunflower and the soybean through genetic research, creating the "sunbeam."

The future here is limitless. To meet the growing demand for food, crops will be developed that are more nutritious than today's. Researchers are now working at retrieving food protein from tobacco before the leaves are processed, with no ill effect on tobacco quality. Self-fertilizing plants are being developed that will reduce the need to add chemicals to the soil. In the future, there will be plants that are naturally immune to pests and disease that farmers today must control with chemicals. Even the orchards of the future will change as dwarf orchards are developed to enhance efficient harvesting.

Some of the changes predicted for agriculture are almost upon us; others are years away. Many predicted products and technologies may never leave the laboratory or the drawing board. While the daily life of the farmer will still center on the fundamental activities of planting, harvesting and marketing, the farmer of tomorrow will have to master many things in addition to basic agricultural training.

The farmer will spend less time in the fields and more time in the office. To make cost-effective decisions, the farmer will need to understand market forces and how they change with the economy. A basic knowledge of electronics and computers will permit the farmer to adapt to changes in telecommunications and data processing. By keeping up with advances in technology and science, the farmer of tomorrow will be able to respond imaginatively, producing more crops, in wider variety, with less hours of labor. Indeed, there are no limits to the technology with which farmers must be acquainted.

As today's young people enter agriculture as a career, they can look forward to more productive farming and added advancement in research that will increase our productivity and maintain America as the agricultural giant of the world. The farmer of tomorrow faces repeated adaptations to change and a lifelong effort to keep informed.

About the Author

David A. Hill is the senior research associate for agriculture for the House of Representatives' Republican Study Committee. Prior to this assignment, Hill spent three years as assistant director for national affairs for the American Farm Bureau Federation.

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LECTURE NOTES

MODULE 1: Introduction to Energy Conservation in Agriculture

The purpose of agriculture is to capture solar energy in plants, then to convert plants and plant products into food, fiber and other products. The goal is to achieve a high yield of quality products at low cost, thus maximizing profits.

Nonsolar energy (gasoline, diesel fuel, LP gas, natural gas, fuel oil, electricity) is used in agriculture to increase productivity and reduce the need for human labor. Production agriculture uses only 3% of the energy consumed in the country. But to those involved, it is an essential and costly part of the business.

Transparency 1

Types and amounts of fuels and electricity used in farming are shown here. Gasoline and diesel fuels (6.3 billion gallons) are primarily used in tractors, trucks and other farm engines. Natural gas operates irrigation pumps and heats farm buildings. Crop drying is a heavy user of LP gas and fuel oil.

Transparency 2

This chart indicates uses of energy consumed on American farms. When broken down in this manner, note that energy "invested" in fertilizers and pesticides exceeds all other categories. Vast quantities of natural gas are used in the manufacture of Nitrogen fertilizers. Other big users of energy are field operations and transportation. Each use of energy is important to the farmer paying the bills.

Price and availability of fuels and fuel-based products have become major concerns for farmers, greenhouse operators and others involved in food and fiber production. From a price of less than 30¢ per gallon in 1972, gasoline has risen to about $1.50 in 1982. Costs of other fuels and products made from fuels have risen accordingly.

To remain in business, farmers must make a profit. Energy costs are making it more difficult. Several options are available to agriculturalists to cope with increasing costs and scarcity of energy:

Transparency 3

Options:

1. Reduce energy use
2. Substitute enterprises that require less energy
3. Substitute plentiful for scarce forms of energy
4. Use alternative energy sources
5. Modify agricultural enterprises to increase efficiency
6. Cease farming

Can you give examples of how each of these options might be implemented?

What are farmers doing to conserve fuel and energy? The International Harvester Company, in 1981, surveyed farmers to find out. They asked the question, "What are you doing to improve fuel efficiency in your operation?" From across the USA, 333 farmers answered:

Transparency 4

Survey Results:

59%	Cut out some tillage operations
44%	Combined some field operations to save trips
44%	Reduced numbers of trips to town
38%	Use more chemicals to eliminate cultivation
31%	Stepped up tractor maintenance
23%	Enlarged existing equipment
21%	Pay more attention to slippage
20%	Consolidated the operation to save road miles between fields
18%	Bought a more efficient tractor
12%	Started keeping fuel records
10%	Switched to no-till planting
8%	Other
4%	Have done nothing to improve fuel efficiency

An interesting list. Perhaps you can do or have done some of these things, too. But notice that this lists deals only with tractor and machine operations. Energy conservation measures can also be applied in livestock and poultry operations, in our homes and with our personal automobile usage.

As we discuss energy problems, recognize that there are two types of energy costs or consumption in agriculture -- direct and indirect.

Transparency 5

Direct:

Fuel (gasoline, LP gas, diesel fuel, natural gas, fuel oil, other)
Electricity

Indirect:

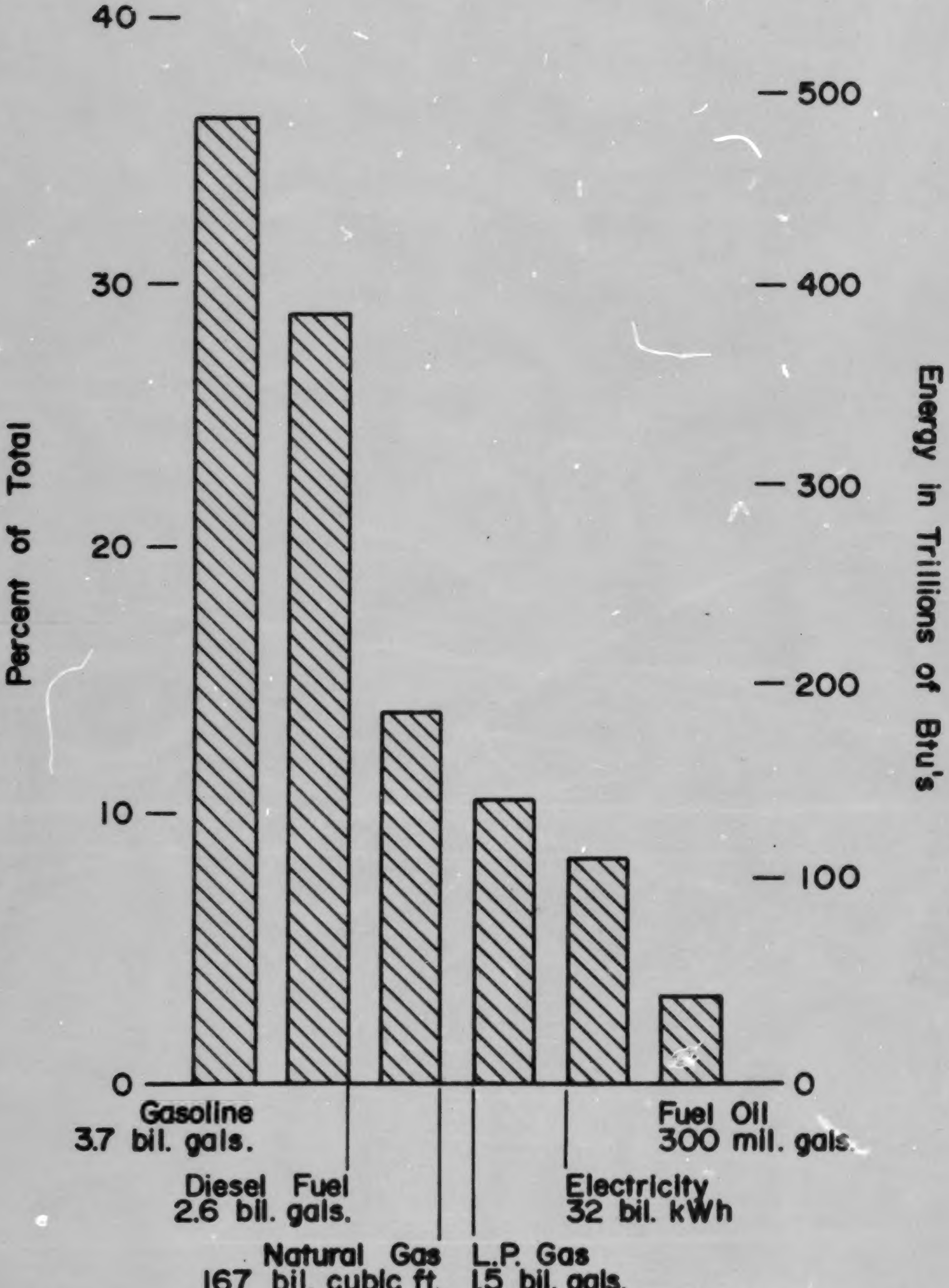
Mining, refining, casting and forming metals in equipment/machinery
Energy expended in refining fuels and lubricants
Transportation of supplies, equipment, produce
Manufacture of feeds (concentrates) and supplies
Production of coal and oil to generate electricity
Production of grain and hay as livestock feed

If we are really concerned about energy, we will be considering ways to conserve energy resources in any topic we study. But remember, energy conservation is primarily a matter of economics. People (including farmers) will cut back on energy usage for short periods of time out of a sense of duty or patriotism, but over the long-run, they will continue only if it's to their economic advantage. Our contribution to energy conservation in agriculture must be:

Transparency 6

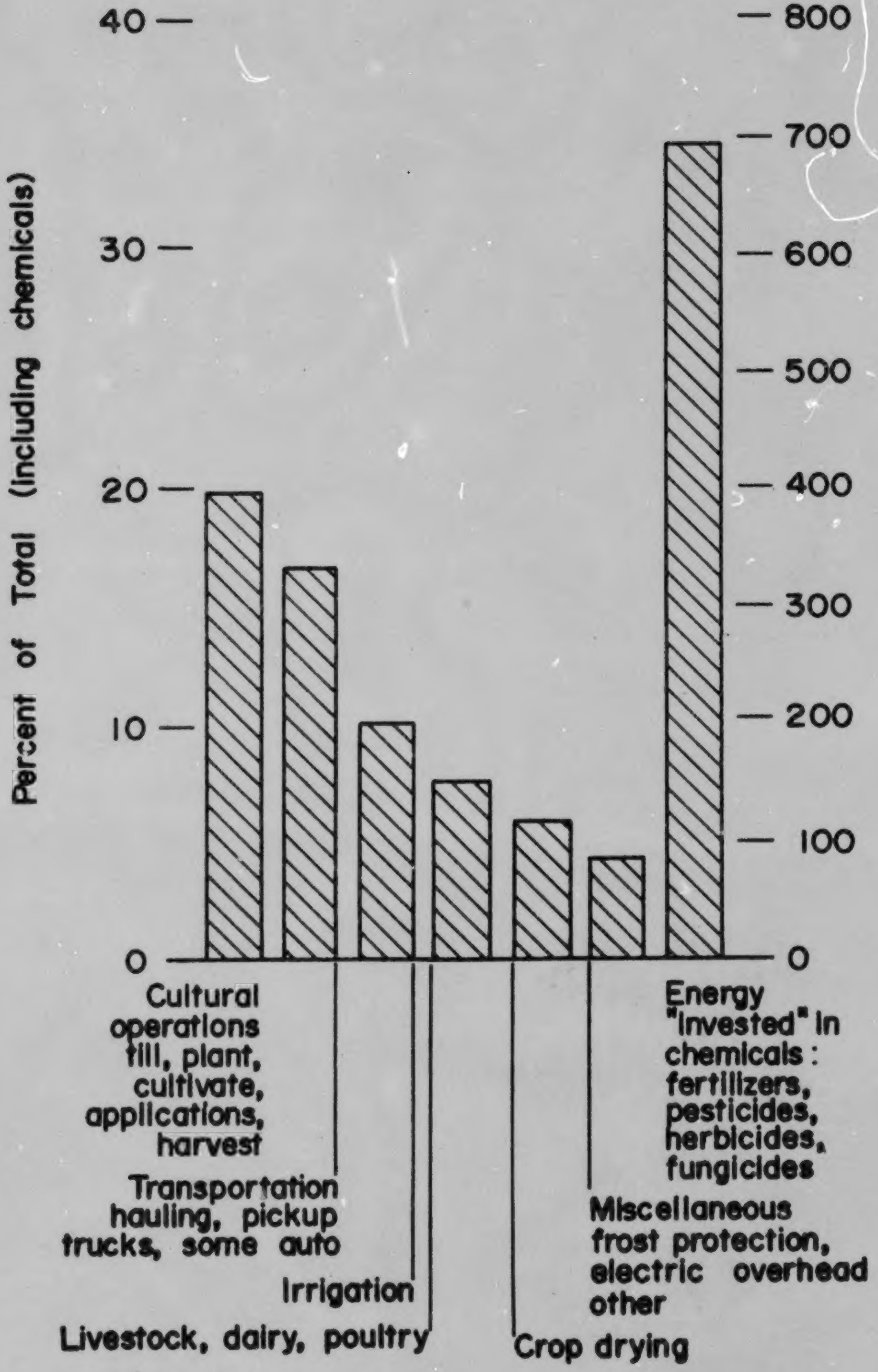
1. To reduce energy consumption while maintaining or increasing production, or
2. To increase production without increasing energy consumed.

Energy Efficiency = producing the maximum amount of products with the least amount of energy



TYPES OF ENERGY USED IN AGRICULTURE

Transparency 1



ENERGY USED IN AGRICULTURE, PLUS FERTILIZERS AND CHEMICALS

Transparency 2

OPTIONS

1. REDUCE ENERGY USE
2. SUBSTITUTE ENTERPRISES THAT REQUIRE LESS ENERGY
3. SUBSTITUTE PLENTIFUL FOR SCARCE FORMS OF ENERGY
4. USE ALTERNATIVE ENERGY SOURCES
5. MODIFY ENTERPRISES TO INCREASE EFFICIENCY
6. CEASE FARMING

Transparency 3

SURVEY RESULTS

"WHAT ARE YOU DOING TO IMPROVE FUEL EFFICIENCY IN YOUR OPERATION?"

59%	CUT OUT SOME TILLAGE OPERATIONS
44%	COMBINED SOME FIELD OPERATIONS TO SAVE TRIPS
44%	REDUCED NUMBER OF TRIPS TO TOWN
38%	USED MORE CHEMICALS TO ELIMINATE CULTIVATION
31%	STEPPED UP TRACTOR MAINTENANCE
23%	ENLARGED EXISTING EQUIPMENT
21%	PAY MORE ATTENTION TO SLIPPAGE
20%	CONSOLIDATED THE OPERATION TO SAVE ROAD MILES
18%	BOUGHT A MORE EFFICIENT TRACTOR
12%	STARTED KEEPING FUEL RECORDS
10%	SWITCHED TO NO-TILL PLANTING
8%	OTHER
4%	HAVE DONE NOTHING TO IMPROVE FUEL EFFICIENCY

Transparency 4

ENERGY CONSUMPTION IN AGRICULTURE

DIRECT

FUEL (GASOLINE, LP, DIESEL, NATURAL GAS, FUEL OIL, OTHER)

ELECTRICITY

INDIRECT

MINING, REFINING, CASTING, FORMING METALS

REFINING FUELS AND LUBRICANTS

TRANSPORTATION OF SUPPLIES, EQUIPMENT, PRODUCE

MANUFACTURE OF FEEDS (CONCENTRATES) AND SUPPLIES

PRODUCTION OF COAL AND OIL TO GENERATE ELECTRICITY

PRODUCTION OF GRAIN AND HAY AS LIVESTOCK FEED

ENERGY CONSERVATION IN AGRICULTURE

1. REDUCE ENERGY CONSUMPTION WHILE MAINTAINING OR INCREASING PRODUCTION

OR

2. INCREASE PRODUCTION WITHOUT INCREASING ENERGY CONSUMED

ENERGY EFFICIENCY = MAXIMUM PRODUCTION WITH LEAST ENERGY

Transparency 6

STUDENT COMPETENCY SHEET

Module 2: Energy Conservation in Livestock and Poultry Production

Competency 1: Produce milk with minimum energy expenditure

Introduction:

Down through the ages, the cow has been known as the foster mother of mankind. She has given us milk, meat, leather, and bones for fertilizer. In some parts of the world, the cow is the major source of farm power, serving as a draft animal in pulling carts, plows and other implements.

In this country, milk and meat from dairy animals are major contributors to our food supply. Over 10 million dairy cows produce milk for American consumers. In doing so, a great deal of fuel and electricity are used. Feed production, processing and handling, waste disposal, ventilation, lighting, water supply and heating, and milking and milk cooling all consume energy.

Close examination of a dairy operation will generally reveal potential for improved management practices which will reduce energy consumption and expense. Some are obvious. Others are easily overlooked. In this lesson, you will discover some of the ways to plug energy leaks in producing dairy products.

Resources and Equipment:

WVU Extension Circulars
    SE-8.0, Energy Conservation on the Dairy Farm
    ST-11.0, Ventilation of Dairy Buildings
    SE-8.1, Energy Conservation in the Milk House
    NRAES FS-18, Dairy Farm Heat Exchangers for Heating Water
Dairy Science textbook (e.g., Livestock and Poultry Production)

Learning Activities:

1. Read WVU Extension Circulars SE-8.0, Energy Conservation on the Dairy Farm, and ST-11.0, Ventilation of Dairy Buildings. Answer the following questions:

    a. How can the dairy barn ventilation system be made to operate efficiently?

    b. How can energy used for lighting be reduced?

    c. How can less energy be used in feed preparation?

    d. How is energy consumption influenced by the ration fed to dairy cattle?

2. Much of the energy consumed in milk production is that which has been expended in production and processing of feed. Efficient use of feed calls for healthy animals. Using available references (e.g., Livestock and Poultry Production, by Bundy and Diggins), identify at least 10 practices that will help insure herd health.

3. Read WVU Extension Circular SE-8.1, Energy Conservation in the Milk House. Be able to name and explain three methods of conserving energy in milk house operation, and list five conservation practices applied to water heating.

4. On a field trip, closely examine your own dairy operation or one in your community. Identify and describe ten practical measures which can be taken to conserve energy and increase profits.

Evaluation:

1. Turn in the information requested in Learning Activities #1 and #2.

2. Turn in your list of energy conservation measures identified in Learning Activity #4. At least 5 of the measures identified should deal with milk house operations and water heating.

MILK GENERATOR

SE-8.0

COOPERATIVE EXTENSION SERVICE
West Virginia University
Center for Extension and Continuing Education

Agricultural Engineering

energy conservation on the dairy farm

Evidence of today's energy shortage can be found in every aspect of agriculture. Particularly noticeable to the farmer, however, is the high cost of fuel and electricity. At present, milk production in the United States requires annually about 550 kilowatt hours of electricity, six gallons of L.P. gas, and 18 gallons of gasoline equivalent per cow for farm tasks directly related to the dairy operation—milking, milk cooling and manure removal. This requirement equals an energy cost per cow to approximately $35 a year at current prices.

Many dairymen feel that they cannot practically alter their operations to use energy more efficiently than they already do. There are, however, several areas in which existing operations can conserve energy without major investments in new equipment.

A first step in the energy saving process is to carefully record energy usage. From this record, the dairyman can discover which areas of the operation are costing him excess energy dollars. Through careful energy management, a dairy farmer might save 10-20 percent of the energy he currently uses. For a 50-cow operation this means a dollar savings of $175-$350 per year depending on price levels.

Areas in which energy can be conserved on the dairy farm include among others, the proper use and maintenance of fans, lighting and motors.

VENTILATION FANS

The amount of ventilation required in dairy buildings varies. Fans are helpful in removing heat and moisture in the milking area and from areas where cattle are confined. Electric fans are rated by the cubic feet of air they move per minute. Most fans have two or more speeds and should be operated only when necessary, not continually. In summer, manual operation is usually more economical than allowing the fan to be controlled by an automatic thermostat. Energy is wasted when fans run unnecessarily during certain times of the day when the area does not need to be cooled. One fan motor operating continually will consume more energy than the mechanized feeding system on some dairy farms. A ⅓ horsepower motor that runs continually consumes 7253 kilowatt hours per year.

Regular maintenance and cleaning allow the fan to operate more smoothly and improve its efficiency. Electric motors should be checked and oiled regularly. Cleaning off the dust and oil that builds up on the fan blades will save five to 10 percent on energy in winter months, and help fans move more air in the summer months. Cleaning the fan louvers is also a good practice.

Before you buy check to make sure that the multispeed fans you buy are not the resistance element type. This type of motor draws the same amount of current whether it is operating at half or full speed.

Open barns increase ventilation

Use of skylights cuts electricity costs

COMPARISON OF LAMPS

Type of lamp	Size by watts	Average output in lumens	Average hours of life	Average lumens per watt*
Incandescent (standard)	25	225	750 to 1,000*	9
	40	430		11
	50	630		13
	60	810		14
	100	1,600		16
	150	2,500		17
	200	3,500		18
	300	5,490		18
Fluorescent (standard)	15	660	18,000	34
	20	1,000		40
	40	3,200		60

*Longer life lamps (up to 3,500 hours) are available at a higher initial cost. They produce 10-15 percent fewer lumens per watt.

LIGHTING

Lighting costs can be effectively reduced by as much as 25 percent. Although lighting is normally only 3-6 percent of a dairy's total electric bill, lights left burning needlessly use energy and dollars. Just one 150 watt bulb left on over night (12 hours) consumes 1.8 kilowatt hours which could cost $20 in a year's time.

To reduce operating costs for lighting, relamp the lighting system with lower wattage bulbs or add switches to permit single or small group operation of lamps whenever possible. Two bulbs might be replaced with one that has comparable light output. Unnecessary lamps may be removed. When removing a fluorescent lamp, disconnect the primary side of the ballast because the ballast draws energy even after the lamp is removed.

For indoor lighting, fluorescent bulbs provide about four times as much light per unit of energy used as the incandescent bulbs. And the fluorescent tubes will last seven to 10 times as long as incandescent bulbs. Use fluorescent lighting to save electricity costs and reduce heat produced by the lighting. When planning lighting for new buildings, take advantage of the sunlight. Use as many windows and skylights as possible.

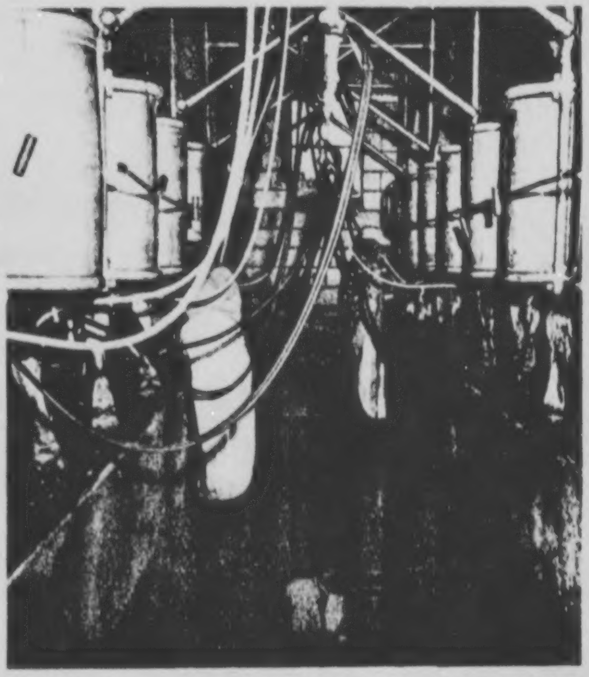
For outdoor light, consider mercury, metal halide, or high pressure sodium lamps instead of incandescent. These are two to four times more efficient.

Clean lighting fixtures regularly so the accumulation of dirt does not reduce the amount of light put out. Dim light bulbs, especially fluorescent, should be replaced because their efficiency has dropped.

ELECTRIC MOTORS

Electric motors vary primarily in the amount of starting torque developed and the starting current required. These requirements depend on the equipment to be driven. Fans have low starting torque and may utilize split-phase motors. For medium starting torque, as required by vacuum pumps, capacitor start-induction motors may be used. Capacitor start-capacitor run or repulsion-induction motors are used for silo unloaders and barn cleaners which require high starting torque.

If expanding or purchasing new equipment, consider installing three-phase motors. Three-phase current must be supplied for a three-phase motor, but is more efficient to operate, more dependable and cheaper to purchase than a single-phase motor.



Milking machines are transferred from one line of cows to another

Collecting wastes for feed recycling

Electric motors require little maintenance. However, the following items should be checked at least once a year.

1. Remove dust and dirt from motor to ensure proper cooling.
2. Check bearings for wear. Excessive side or end play may cause excessive current usage.
3. Oil bearings. Do not over-lubricate. It is just as bad as too little lubrication.
4. Clean starting switch contacts or brushes. Use a very fine sand paper, not emery cloth.
5. Check to be sure the motor shaft turns freely. Tighten or misaligned bearings will cause the motor to overheat and waste energy.
6. Check belt pulleys to be sure that they are secure on their shafts.
7. Check belt tension and replace worn belts.

One use of electric motors on many dairy farms is to power a feed mill. Efficient digestion of grains by dairy cattle requires the cracking, crushing or abrading of the grain by a mill. When a dairyman purchases a feed mill, he may choose between a roller mill or hammer mill, among others.

Roller mills cost more than hammer mills, but their cost is offset because they require less energy and they produce less fines, or very small feed particles that can settle out of mixed feed, varying the texture of the ration. Energy required per ton of feed ground depends on the screen size, moisture content of the grain, and the type of grain processed. For example a hammer mill might require 3.75 horsepower per ton of corn processed while a roller mill requires 1.5 horsepower per ton.

ENERGY NEEDS OF DAIRY CATTLE

The conservation of energy in a dairy farm operation is often considered only in terms of the usage of electrical power such as motors, lights and tractors. Yet, the greatest usage of energy is in the ration consumed by dairy cattle.

The unit for measuring heat, known as calorie, is the amount of heat required to raise the temperature of one gram of water from 14.5 to 15.5°C. A thousand calories are called kilocalories and a million-calories are called megacalories. A megacalorie is the amount of heat required to raise the temperature of a metric ton (2200 lbs) of water 1°C.

A typical Florida dairy ration will contain approximately 62 megacalories of energy. The average dairy cow will consume from 35 to 40 lbs. (24 MCal) of ration per day or about 1 lb. of ration for 1 lb. of milk produced in a total herd. Since a certain amount of energy is needed for body maintenance, a herd of high producing cows needs less feed than a herd of lower producing cows producing a similar amount of milk.

Efficiency in the utilization of a dairy ration is essential for the conservation of energy and in the maintenance of a lower costing feed per unit of milk produced. Factors essential for the efficient utilization of a ration are as follows:

1. A balanced ration
2. Adequate fiber in the ration
3. Consistency in the feeding of dairy cattle

Dairymen are now experimenting with recycled wastes as a feed source. One method being used is the washing of manure to strain out and re-feed the undigested grain particles. Another practice is the feeding of grain wastes such as chaff and corn cobs. This can be incorporated into the ration and provides bulk and roughage to the cattle.

Another source of energy and fibre being fed to dairy cattle is recycled corrugated cardboard boxes. This supplies more energy than citrus pulp and more usable fibre than cottonseed hulls and is currently much less expensive than either of the above feeds.

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COOPERATIVE EXTENSION SERVICE WEST VIRGINIA UNIVERSITY

Agricultural Engineering

ST - 11

A. W. Selders

VENTILATION OF DAIRY BUILDINGS

Dairy barns need adequate ventilation throughout the year. Without adequate ventilation in cold weather, moisture produced by the animals accumulates inside the building causing deterioration of the building and equipment. Moist, stale air may also seriously affect the health and productivity of livestock.

Mechanical ventilation is a continuous process of bringing in cooler outside air, warming it up with animal heat so that it picks up moisture and then exhausting the warm, moist air outside. As air is warmed about 20 degrees, its moisture holding capacity is doubled. During warm weather, ventilation is needed to remove the excess heat in addition to the moisture.

Insulation

If a ventilation system is to work properly, the walls and ceiling of the building must be insulated. Insulation reduces the heat loss so that heat given off by the animals will warm the incoming air, increasing its moisture holding capacity so the exhausted air will carry off the moisture produced inside the building.

Good ventilation is more difficult in an uninsulated building because much of the heat given by the livestock is lost through the walls and ceiling leaving little or no heat to raise the temperature of incoming air. In cold weather, if the temperature of the incoming air is not increased, little or no moisture will be removed.

In uninsulated buildings, the inside surfaces of the walls and ceilings will be almost as cold as the outside temperature. When warm, moist air strikes the cold surface, moisture condenses causing dripping.

For proper ventilation of dairy buildings, ceilings should have a minimum R (resistance to heat flow) value of about 14. Walls should have a minimum R value of about 11. Table I gives typical R values for various building materials.

Vapor Barrier

A vapor barrier close to the warm surface in dairy buildings is needed to protect the insulation from moisture damage and to reduce moisture penetration into concealed building materials. A continuous film of 4- or 6-mil plastic polyethylene sheet stapled to framing immediately under the wall or ceiling covering is an excellent vapor barrier. Rigid, plastic foam insulation boards need no vapor barrier if the joints are sealed. Certain laminated boards with plastic facing and metal roofing sheets, with edges sealed with plastic or asphalt compounds, can provide a good vapor barrier.

TABLE I. TYPICAL R VALUES FOR VARIOUS BUILDING MATERIALS.[1]

Material	R value per inch thickness
Building Boards	
Asbestos-cement board	0.25
Fiber board (33#/ft^3)	1.82
Plaster board	0.89
Hardboard	0.72
Sheathing board (20#/ft^3)	2.63
Insulating Blankets	
Mineral wool (rock, slag or glass)	3.70
Wood fiber	4.00
Cotton fiber	3.85
Boards and Slabs	
Polystyrene (foamed)	3.78
Cork	3.74
Cellular glass	2.60
Urethane (foamed)	6.25
Loose Fill	
Mineral wool	3.80
Sawdust, shavings	2.22
Vermiculite (expanded)	2.21
Wood fiber	3.89
Masonry	
Cement mortar	0.20
Regular concrete	0.08
Cement plaster	0.20
Woods	
Hardwoods	0.91
Softwoods	1.25

Material	Thickness (inches)	R Value
Air Space		
Vertical	3/4 to 4	0.95
Vertical (reflective lining)	3/4 to 4	2.85 (av.)
Air Surface Films		
Outside		0.17
Inside		0.68
Masonry Units		
Concrete blocks	4	0.71
Concrete blocks	8	1.11
Same core filled	8	1.93
Concrete blocks	12	1.28
Cinder aggregate	4	1.11
Cinder aggregate	8	1.72
Cinder aggregate	12	1.89
Light weight aggregate (24 lbs)	8	2.18
Light weight aggregate (filled	8	5.03
Light weight aggregate (38 lbs)	12	2.48
Light weight aggregate (filled)	12	5.82
Roofing		
Asphalt shingles	1/4	0.44
Built-up roofing	3/8	0.33
Windows[2]		
Single pane		0.94
Double pane (air space)	1/4	1.64
Single pane (with storm sash)		1.54 (av.)

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[1] Information adapted from ASHRAE Guide and Data Book 1965.

[2] Total resistance including air films.

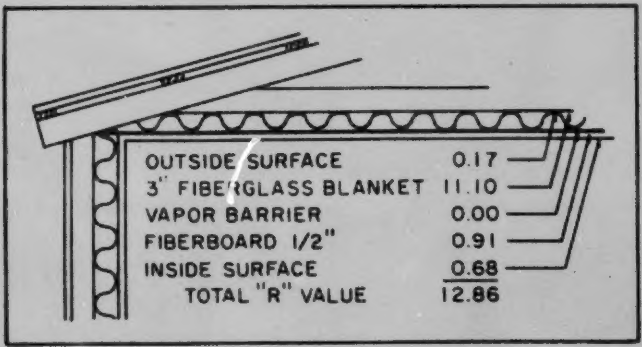

FIGURE 1. INSULATED WOOD FRAME CEILING. To determine the total R, add values for the various building materials as indicated.

For additional information on ventilation, see ST-12, Slot Inlets For Exhaust Type Ventilation Systems.

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COOPERATIVE EXTENSION SERVICE
West Virginia University
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SE-8.1

Agricultural Engineering

energy conservation in the milk house

The milk house is a major site of energy consumption on a dairy farm. Equipment used to heat water and cool milk requires large quantities of electricity. Energy costs have increased substantially in recent years and indications are that they will continue to climb. Water supplies also have become critically low in many parts of the country. Efforts should be made to minimize the amount of energy and water used to perform the necessary functions related to the production of high quality milk. Energy conservation not only will be economically rewarding for the milk producer but also will conserve our diminishing natural resources.

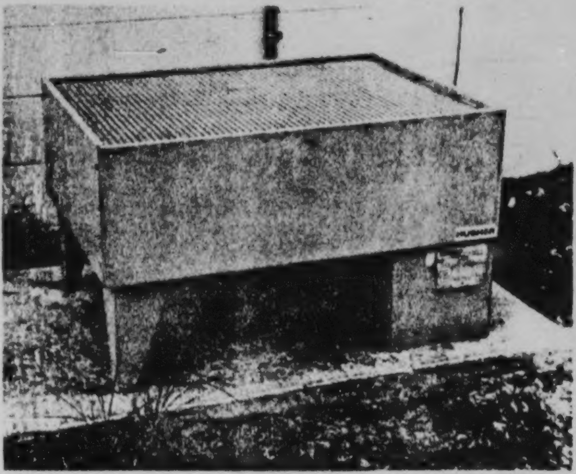
MILK COOLING

Two popular methods are used to cool milk: placing the milk in direct expansion tanks and using a heat exchange between milk and ice water. Both methods of cooling require similar types of refrigeration units. Major components of the refrigeration system in which energy can be conserved are the compressor and the condenser.

On milk cooling tanks, the compressor and condenser are usually integral units. The compressor increases the pressure on the vapor form of the refrigerant. The condenser then cools the compressed vapor until it changes to a liquid state. In this process, a substantial quantity of heat is produced and exhausted into the surrounding environment.

Air Fin Condensers

Condensers on farm tanks are usually of the air fin type. Ambient (surrounding) air is circulated over the condenser coils. Because of this, the temperature of the air has a direct effect on the efficiency of the refrigeration unit. Location of the refrigeration unit in the milk room will unnecessarily increase the temperature of the milk room and result in a loss of cooling efficiency. This unit will be most efficient if it is located outside the milk house. If the refrigeration unit must be in the milk house, proper ventilation such as windows or fans should be provided to keep the milk house temperature as low as possible.

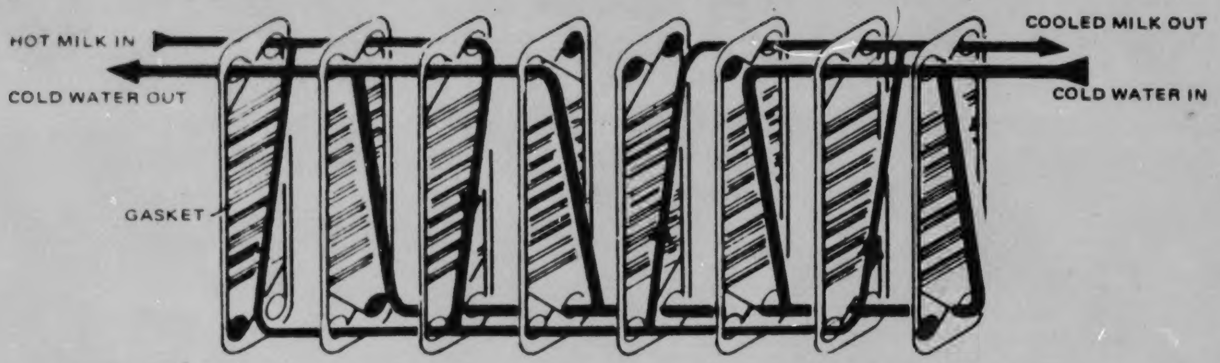


Condensers on farm tanks are usually of the air fin type.

Air fin condensers require rapid, obstruction-free movement of air to operate properly. The fins are fine, fragile and easily fouled by dust and other debris. If air flow is hindered in any manner, efficiency will be reduced.

Clean dirty condenser coils and air fins with a vacuum cleaner, air blasts, or by washing with water. Extreme care must be exercised in the cleaning process so the fins are not damaged. They are essential for the transfer of refrigerant heat to air. Bent, flattened, or otherwise damaged fins will not function properly.

Provide adequate space around the condenser for proper air circulation. Positioning the condenser near walls or other obstructions that hinder either air intake or exhaust will reduce its efficiency. Whenever



Milk and refrigerant flow through alternate plates allowing the transfer of heat from milk to refrigerant.

the condenser is outdoors, care must be taken to remove anything that might be inadvertantly placed on or near the unit. Weeds and other vegetation should be cleared from around it regularly.

Cooling With Water

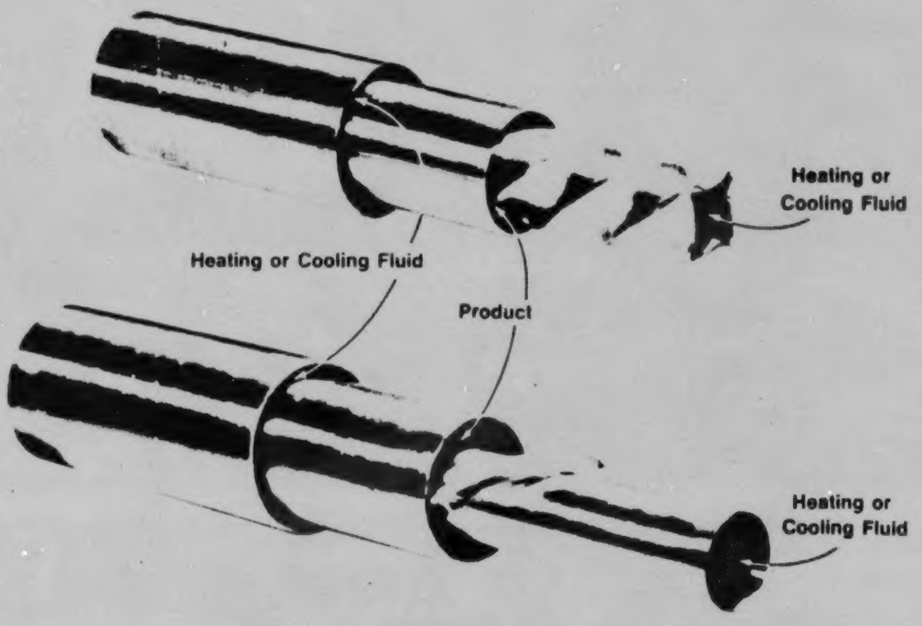
Pre-coolers(heat exchangers) can be installed between the milking parlor and the storage tank. Precoolers are either plate or tubular in design. Plate heat exchangers consist of a series of thin plates with each plate sealed individually. Milk and refrigerant flow through alternate plates allowing the transfer of heat from the milk to the refrigerant.

Several types of tubular heat exchangers are available. The most common type is a triple tube arrangement. This includes a small pipe through which refrigerant flows. This small pipe is enclosed in a larger pipe. Milk flows through this pipe and is in contact with the small pipe containing the refrigerant.

A third larger pipe is used to enclose the other two pipes. Refrigerant is circulated through the large pipe and is in contact with the pipe containing the milk. This arrangement allows milk to contact refrigerated surfaces on two sides and thus, facilitates heat transfer.

Pre-coolers can be used in several ways, Ideally, a source of refrigerant such as ice water would be circulated through the cooler as milk passes through to the tank. Of necessity, the refrigeration unit and the cooling unit will be separated. If the distance between the two units is too great, heat gain to the refrigerant will be higher than necessary and will reduce the cooling capacity of the refrigerant. To minimize the size of the refrigeration unit, and to prevent heat gain to the refrigerant, both the refrigeration and cooling units should be as close together as possible.

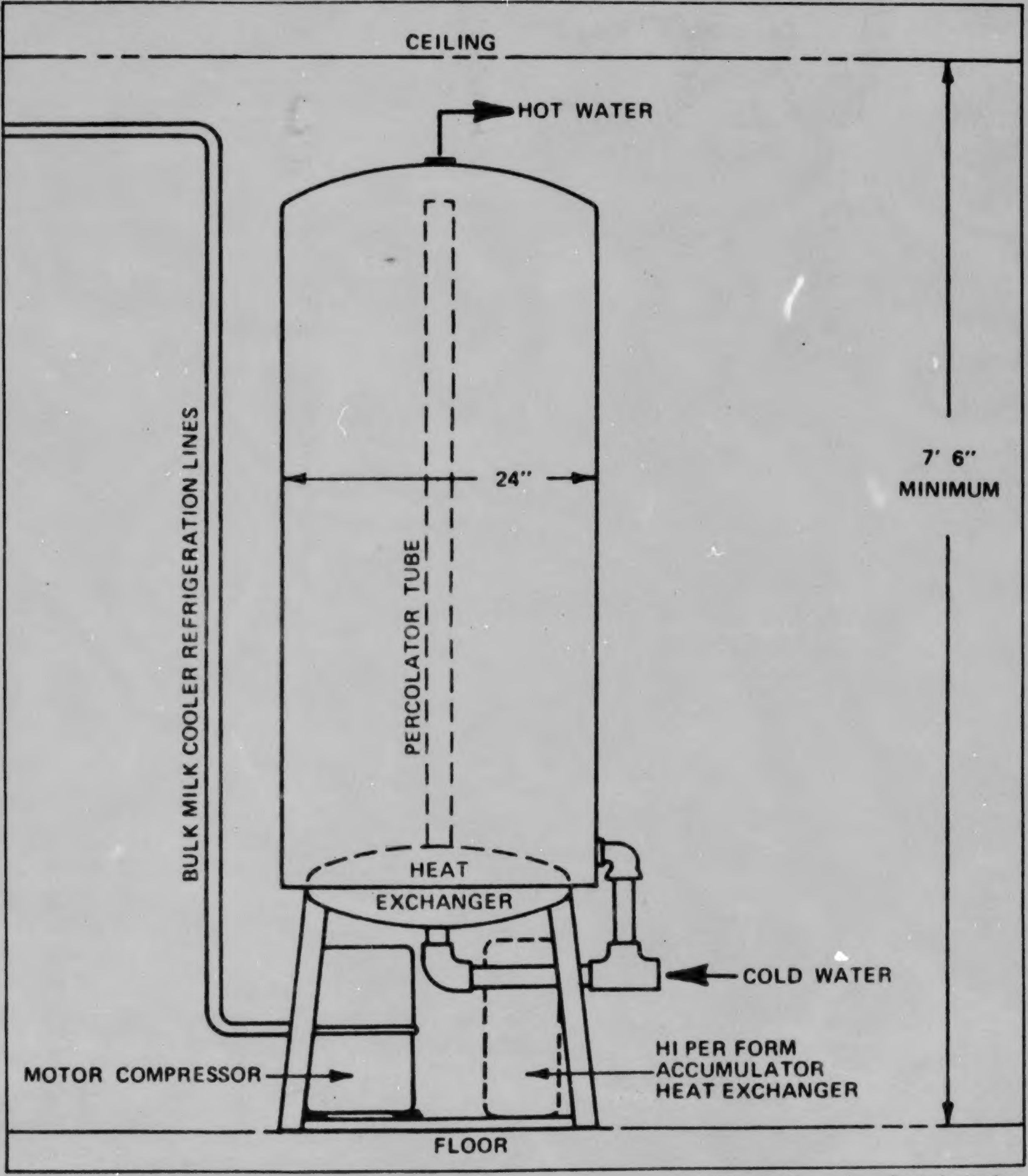
When possible, and consistent with sanitation regu-



Triple tube heat exchangers.

lations, pipes carrying refrigerant to the cooling unit should be insulated. Insulation of the refrigeration unit will vary depending upon the manufacturer. A unit with the best insulation properties should be chosen. Locate the unit in an area that is shaded for at least part of the day.

The use of well water in combination with precoolers also offers many energy saving opportunities. It is possible to remove 20 to 30 percent of the heat from milk with well water. This can save energy by decreasing the amount of cooling that would have to be done by the refrigeration unit on the bulk tank. Or it could provide the extra refrigeration capacity needed by a tank that was not quite adequate because of an increase in herd size or milk production and, thus, delay the purchase of a new tank.


CEILING
HOT WATER
BULK MILK COOLER REFRIGERATION LINES
PERCOLATOR TUBE
24"
7' 6"
MINIMUM
HEAT
EXCHANGER
COLD WATER
MOTOR COMPRESSOR
HI PER FORM
ACCUMULATOR
HEAT EXCHANGER
FLOOR

Utilizing heat from milk cooling to heat water.

To reduce the amount of water needed in a dairy operation, the pre-cooler can also be used with a cooling tower that would cool the warm water produced in milk cooling This would make it possible to recirculate the same water through the cooling system.

WATER HEATING

The high degree of sanitation needed for producing milk requires a substantial supply of hot water. Conventional water heaters are high energy users. A method has recently been developed to utilize the heat removed in the milk cooling process to heat water. This is accomplished by utilizing water rather than air to condense the refrigerant vapors.

A heat exchanger is constructed that brings cold water into contact with condenser. As the refrigerant changes from a gaseous to liquid state the heat given off is taken into the water. Depending upon design, this process can heat water up to 140° Fahrenheit, hot enough for milk house use. Significant energy and economic savings are possible.

Pre-cooling milk with a heat exchanger utilizes the heat removed in the milk cooling process to heat water. Because of the heat it gained from the milk, water that has been used to cool milk will be warm, not hot. This water can be circulated through the milk house water heater, which reduces the amount of energy needed to heat water for a dairy operation. Or this warm water from the pre-cooler can be directly diverted to the holding pen sprinkler.

Many dairies have a sprinkler system in the holding pens to wash the udder and underside of cows before the cows enter the milking parlor. This not only cleans the udder, but also helps stimulate milk letdown during cool seasons of the year. This process increases milk production slightly and is virtually a free source of heated water.

Visible economic gains can be achieved through other energy conservation practices applied to water heating. These include:

1. Purchase water heaters that will provide an adequate supply of hot water, but avoid water heaters that are much larger than needed.
2. Make sure the water heater is properly insulated.
3. Do not use hot water excessively. Make sure it is hot enough for the required purpose, but keep the water temperature minimum—no higher than the maximum temperature needed.
4. Use only the required amount of hot water and detergent for cleaning operations.
5. Examine all hot water faucets and repair those that leak.
6. Do not use hot water where cold water could be used.

CONCLUSION

Progressive dairy farmers will constantly seek new methods of conserving energy and water resources. When conscientiously applied, these practices not only decrease energy and water consumption, but will also cut expenses and make for a more profitable operation. Your local cooperative Extension office will have more information on energy conservation ideas.

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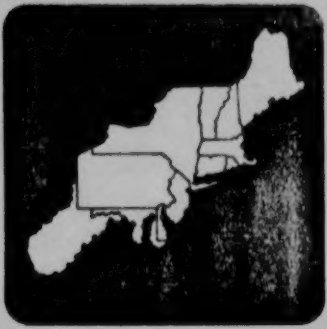

Agricultural Energy Management

Dairy Farm Heat Exchangers for Heating Water

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R. K. Koelsch, Cornell University, Ithaca, NY

Milk cooling and water heating may consume up to 40% of the electric energy used on modern dairy farms. You can save energy and cut the cost of heating water in a dairy operation by more than half by installing a heat exchanger to recover the heat now being lost to the air from the milk refrigeration system.

Heat is available from a milk tank refrigeration unit from two sources. One is the heat that is removed from the milk to cool it from about 90°F to 40°F or below. The second is from the electrical energy used to run the compressor. Most of this heat is contained in the hot gas which comes from the compressor.

Types

There are two ways to recover this heat. One is to add a heat exchanger between the compressor and the existing air-cooled condenser, along with a water storage tank and a circulating pump. Figure 1a shows a schematic of such an installation. A pump circulates water from the water storage tank through the heat exchanger when the compressor runs and the temperature in the heat exchanger is above the temperature of the water in the storage tank. The conventional water heater is thus supplied with water in the 100°F to 140°F range rather than cold water (50°F) from the well.

The second type of exchanger is a special water-cooled condenser unit instead of the typical air-cooled condenser (Figure 1b). It would normally be considered when installing a new system or replacing an old, worn out unit. One design variation incorporates the heat exchanger into the storage tank. Because hot water rises to the top of the tank, two different temperatures of water can be removed at different levels of the tank (Figure 1c). The hottest water at the top of the tank is about 140°F. Water removed from a tap at the center of the tank is lukewarm, and is often used for washing udders and general cleanup. This heat exchanger is available as either an add-on or complete condensing unit.

A water-cooled condenser recovers more heat than an add-on unit because all heat from the refrigerant is transferred to the water and an add-on unit may still lose some heat through the condenser. An add-on exchanger may recover as much as 70% or as little as 15% of the milk heat depending on the compressor head pressure setting and the time of water use. Dairies with normal water use patterns can expect to recover at least 40% of the milk heat from a properly adjusted add-on heat exchanger.

Expected Savings

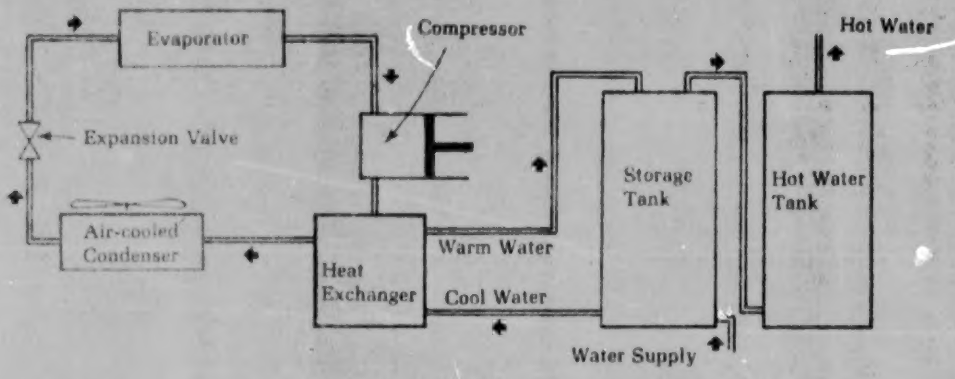
You must know 1) your hot water use, and 2) the amount of milk cooled daily before you can estimate the potential savings of a heat exchanger. About 2 to 3 gallons of warm to hot water per cow per day is used by many dairies. Some use less than one gallon per cow per day which suggests it is possible to save even more by figuring ways to cut hot water use. Use Table 1 to estimate water use.

Table 1. **Volume of milkhouse and parlor wastes.**

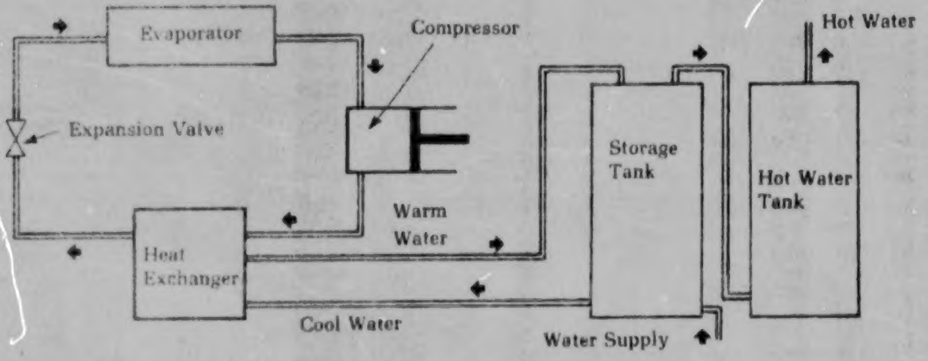
Washing Operation	Water Volume
Bulk Tank	
Automatic	50-60 gal/wash
Manual	30-40 gal/wash
Pipeline	
In parlor	75-125 gal/wash
(Volume increase for long lines in a large stanchion barn)	
Pail milkers	30-40 gal/ wash
Miscellaneous equipment	30 gal/day
Cow prep.	gal/wash per cow:
Automatic	1-4 1/2
Estimated Average	2
Manual	1/4 - 1/2
Parlor Floor	40-75 gal/day
Milkhouse Floor	10-20 gal/day
Toilet	5 gal/flush

Figure 1. Types of Heat Exchangers

a. Add-on Heat Exchanger retains present Air-cooled condenser.


Evaporator
Compressor
Hot Water
Expansion Valve
Storage Tank
Hot Water Tank
Air-cooled Condenser
Heat Exchanger
Warm Water
Cool Water
Water Supply

b. Complete Condensing Heat Exchanger eliminates Air-cooled Condenser


Evaporator
Compressor
Hot Water
Expansion Valve
Storage Tank
Hot Water Tank
Warm Water
Heat Exchanger
Cool Water
Water Supply

c. Complete Condensing Heat Exchanger Producing Two Different Water Temperatures

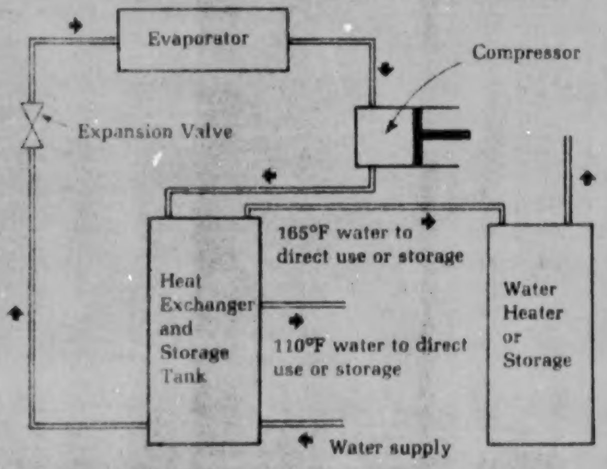

Evaporator
Compressor
Expansion Valve
165°F water to direct use or storage
Heat Exchanger and Storage Tank
110°F water to direct use or storage
Water Heater or Storage
Water supply

Table 2 and Table 3 list the expected annual value of the hot water produced by both types of heat exchangers.

Table 2. **Expected Savings and Hot Water produced by a Complete Condensing Heat Exchanger that recovers 90% of Heat from Refrigerant Gases.**

Daily Milk Production (pounds)	140°F Water Produced Daily (gallons)	Annual Fuel Cost Savings*, dollars		
		Electricity at 4¢/KWH	Fuel Oil at 50¢/gal	LP Gas at 50¢/gal
1000	8	278	113	170
2000	174	556	225	340
3000	260	834	339	510
4000	346	1112	452	681
5000	432	1390	565	851
6000	520	1669	668	1020
7000	606	1946	790	1190
8000	693	2225	904	1360

*Savings based on using 100% of the hot water produced. This will not be possible in most dairy operations.

Table 3. **Expected Savings and Hot Water produced by an Add-on Heat Exchanger that recovers 40% of Heat in Refrigerant Gases.**

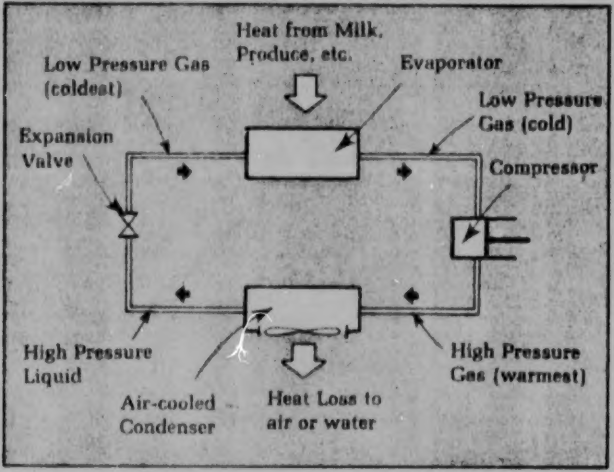
Daily Milk Production (pounds)	125°F Water Produced Daily (gallons)	Annual Fuel Cost Savings*, dollars		
		Electricity at 4¢/KWH	Fuel Oil at 50¢/gal	LP Gas at 50¢/gal
1000	42	111	45	68
2000	84	222	90	136
3000	124	333	136	204
4000	167	445	181	272
5000	208	556	226	340
6000	249	667	271	408
7000	291	779	316	476
8000	334	890	361	544

For example, consider an 80 cow dairy that produces 4000 pounds of milk a day and uses 2 gallons of hot water per cow per day (160 gallons/day). All the hot water from an add-on exchanger can be used, so electric savings are $445 per year. A complete condensing heat exchanger should produce 346 gallons of 140°F water per day. This dairy can only use about half that amount, so the electric savings is still about $500 per year, not the $1112 listed in Table 2. It is very important to have some idea of the quantity of hot water used daily to get a reasonable idea of cost savings.

Heating Water - How Hot?

Most mechanical refrigeration systems, no matter what application, are similar. All have an evaporator, compressor, condenser, and expansion valve (Figure 2). To remove heat from a medium such as air or milk, liquid refrigerant at low pressure passes through an evaporator. The refrigerant boils or evaporates in the evaporator, and in the process, absorbs heat from the medium being cooled. The refrigerant vapor then passes to the compressor. The compressor, powered by an electric motor, is the major energy input to the refrigeration system. In a compressed state, the hot vapor flows through the condenser and gives up heat easily as it changes from a gas to liquid. Still at high pressure, the liquid refrigerant flows through an expansion valve where its pressure is reduced, and continues back to the evaporator.

Figure 2. **Typical Refrigeration System**


Heat from Milk, Produce, etc.
Low Pressure Gas (coldest)
Evaporator
Low Pressure Gas (cold)
Expansion Valve
Compressor
High Pressure Liquid
High Pressure Gas (warmest)
Air-cooled Condenser
Heat Loss to air or water

A heat exchanger can heat water to almost any desired temperature, but the compressor often operates at higher than normal design pressure to heat water above 120° to 140°F. When the head pressure of the compressor is increased the electrical demand also increases and refrigeration efficiency and cooling capacity drops. For these reasons, be sure the head pressure is not altered when an add-on heat exchanger is installed. In general, the head pressure switch controlling fans on the air-cooled condenser should be set between 150 and 190 psia for a R-12 system and between 250 and 300 psia for a R-22 system.

Currently marketed complete condensing heat exchangers frequently operate at higher head pressures than a conventional air-cooled condenser. Upon installation, you may notice it slows milk cooling and increases electrical consumption slightly. These effects normally are not serious unless the present refrigeration system barely cools milk within the required time limit. If this situation exists, ask the heat exchanger supplier how to alter the temperature or pressure switch setting to allow water to bleed off at lower temperatures. This change would allow the refrigeration system to operate at more normal head pressures.

Compressor life might also be reduced if head pressures remain excessively high. At present, however, there is little concern by compressor manufacturers that the head pressure settings used by currently available complete condensing heat exchangers will significantly reduce the lifetime of the compressor.

Well Water Coolers

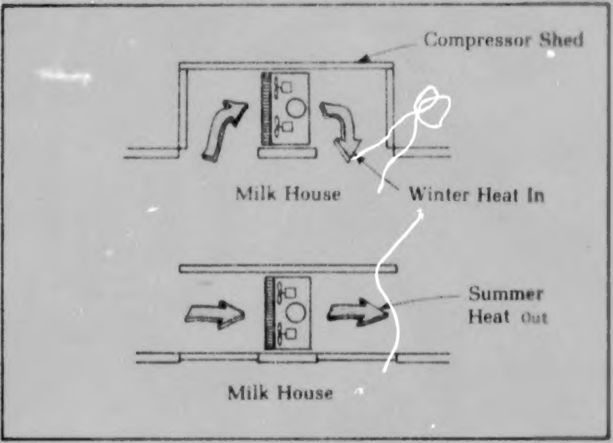
Some dairies install in-line milk coolers that use well water as a coolant. This equipment is used (1) where water is abundant and inexpensive and (2) to boost the cooling capacity of an existing refrigeration system. The tempered water may be used for stock watering or parlor flushing.

In a few cases it may pay to install a heat exchanger together with a well water in-line cooler. Make a careful study of water use before installing both units, though. Often a heat exchanger will pay for itself long before a well water in-line cooler will.

Space Heating

Heat from an air-cooled condenser may be used to heat the milk room. Various arrangements (Figure 2) are possible to change from summer ventilation to winter heat utilization. On dairies with more than 100 cows, it may also be worthwhile to heat the milking parlor or nearby rooms with hot water collected by a heat exchanger. The application of space heating is best suited to complete condensing units. Hot water is circulated from the top of a storage tank by a thermostatically controlled pump through a unit heater and returns to the bottom of the tank. Most designs connect the space heating equipment directly to the potable hot water storage tank.

Figure 2. **Compressor Arrangement to change from Winter Milk House Heating to Summer Ventilation.**



Sizing units

Generally, the size of the heat exchanger is dictated by the size of the refrigeration unit. Follow the recommendations of both heat exchanger and compressor manufacturers regarding heat exchanger selection.

Some manufacturers of heat exchangers provide storage tanks as part of the package. If a storage tank is not provided by the manufacturer a rule of thumb suggests the tank should hold enough water to supply all the hot water needs for one milking. This size will provide adequate hot water, yet still be empty after cleanup. A fresh charge of tap water in the storage tank will then be ready to cool the refrigerant during the next milking; an important step to maintaining refrigeration efficiency.

Installation

Water quality is very important to the successful operation of a heat exchanger. For this reason, the water should be analyzed and results discussed with potential heat exchanger suppliers before purchase. Some heat exchanger suppliers provide this service.

Install the heat exchangers in an area that will not freeze. Avoid long plumbing runs by installing the unit as close as possible to the compressor and water heater. Insulate all hot water lines. Follow manufacturer's installation recommendations.

Maintenance

Clean periodically to remove any scale or other deposits. The frequency of cleaning depends on water conditions, so make provisions for cleaning when installing. Follow the manufacturer's maintenance instructions.

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The Northeast Regional Agricultural Engineering Service is an activity of the Cooperative Extension Services of the Northeast Land Grant Universities and the United States Department of Agriculture.

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STUDENT COMPETENCY SHEET

Module 2: Energy Conservation in Livestock and Poultry Production

Competency 2: Produce pork with minimum energy expenditure

Resources and Equipment:

WVU Extension Circular SE-10.0, Energy Saving Management Practices in Swine Production.

Animal Science Textbook (e.g., Livestock and Poultry Production by Bundy and Diggins.

Learning Activities:

1. Read WVU Extension Circular SE-10.0, Energy Saving Management Practices in Swine Production. Observe that practices discussed are concerned primarily with producing hogs with the least amount of feed. A major portion of the energy used in swine production is in the production, transportation and preparation of grains and supplements.

2. SE-10.0 presents a case for confinement systems. Most West Virginia hog operations are relatively small enterprises which make extensive use of pasture. Using other references (e.g., magazine articles, animal science textbooks), can you present an equally strong case for using pasture in hog production? Consider feed requirements, building and equipment needs, labor, manure disposal and other management practices which influence direct and indirect energy requirements. Write a brief report on your findings.

3. In feeder pig production, five sows will consume approximately 500 bushels of corn and 1,500 pounds of protein supplement per year. There is little, if any, advantage gained by grinding and mixing the feeds for sows. Considerable energy (and time) is used in grinding and mixing feeds, as well as in trips to and from the feed mill.

   Contact your local feed mill and determine costs involved in grinding and mixing the above amounts of feeds if you grow your own corn.

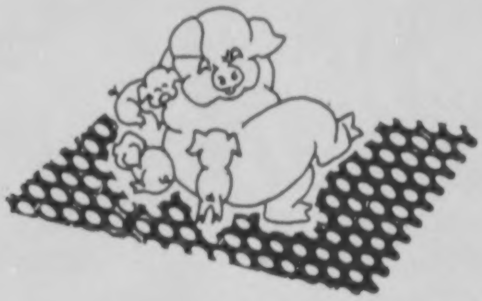
   If you must purchase corn, compare cost of (a) purchasing 500 bushels of corn and 1,500 pounds of tankage or soybean oil meal with (b) purchase of 15,000 pounds of 12% hog feed plus 15,000 pounds of 16% sow feed already ground and mixed.

4. On a field trip, carefully analyze your own swine operation or one in your community. Note how energy (fuel and electricity) is consumed, and observe management practices that might be modified to allow increased production with less feed.

Evaluation:

1. Turn in your written report (Learning Activity #2) and your cost analysis (Learning Activity #3). These will be graded by your teacher.

2. On a written examination, be able to describe three management practices to follow during each of the three phases of swine production--gestation; farrowing to weaning; and growth and fattening--which will contribute to energy efficient pork production on your farm or a farm in your community.



COOPERATIVE EXTENSION SERVICE
West Virginia University
Center for Extension and Continuing Education

SE-10.0

Agricultural
Engineering

energy saving management practices in swine production

In recent years, concern over the decrease in fossil fuel reserves has resulted in the search for alternate sources of energy. Until other means of producing energy are made available, it is the responsibility of all individuals to conserve the energy we now use in the form of electricity, petroleum, and water. Agriculture accounts for the use of three percent of the nation's energy. As the fuel supplies become more scarce, many costs in agricultural production rise. Individuals should conserve energy not only as conscientious citizens but also to cut costs.

In swine production, the key to energy conservation is good management and planning. This involves keeping abreast of the latest developments and infusing them into the operation whenever practical. New practices may seem costly, but often they will save the swine producer time, labor and money in the long run. Several areas to be considered are housing, breeding, young pig care, feeding and disease control.

HOUSING

Many commercial swine producers are considering some system of confinement swine housing. There is justification for this even in Florida for these reasons:

1. Reduced labor -- Labor has become a serious problem because competent, qualified workers often prefer other work.
2. Mechanization -- It is hard to mechanize the operation satisfactorily without confinement. And without mechanization, reduced labor is not possible.
3. Automation -- Confinement is necessary to use automation such as feed conveyors, sprayers, waste disposal equipment, and fans.
4. Increased volume -- With confinement it is possible to increase the volume without increasing the amount of land or labor.
5. Environmental control -- This often results in the improvement of certain performance traits such as feed efficiency, carcass quality and more pigs weaned per litter.
6. Land productivity -- Confinement of a swine operation allows more land to be used for field crops.
7. Waste disposal -- Manure handling becomes more efficient and allows for better use as fertilizer helping offset pasture or crop cost.
8. Operator comfort and convenience -- This has become increasingly important, especially for attracting young farmers to the hog business.

When considering a confinement system some guide lines should be followed. Weighing and handling of feed, cleaning, removing manure, weighing pigs and moving pigs between pens and onto trucks are labor consuming chores which must be done regularly. Therefore, arrange buildings and equipment for convenience and highest labor efficiency which is usually achieved in a straight line layout.

Determine the value of existing buildings. In some cases it may pay to remodel. In others, the old buildings should be torn down, particularly if they interfere with the overall layout. When planning, consider carefully the lay of the land, drainage, prevailing winds and construction methods and materials.

General Recommendations -- All Facilities

Location: Downwind at least 150 feet from farmhouse and run all buildings east and west.

Drainage: Away from the farmhouse and animal enterprises.

Electrical Wiring: Install a system adequate to supply power for all electrical equipment. Use type UF cable. Use wire no smaller than No. 12 for lighting and outlet circuits. Wire for other special equipment such as heaters and mechanical cleaners should be sized according to manufacturer's recommendation.

Sanitation: Use warning signs and sanitizing solutions to control spread of disease by operator and visitors. A good rule is to keep hogs on clean pastures or concrete.

Facilities for Sows, Boars and Herd Replacements

Buildings: They may be small, portable, or larger permanent-type houses, built to allow for normal ventilation in summer, or enclosed on two sides to minimize drafts in winter. Provide individual houses for boars. Divide females into groups that farrow about the same time.

Location: Arrange for access to pasture in season and for ease of feeding, watering and cleaning year around. Locate sow housing near boar housing for convenience at breeding time.

Floor: Floors may be solid concrete or slats.

Size: Allow 15 to 20 square feet area per sow. Allow 10 to 15 square feet area for replacement gilts. Houses or pens for boars or other individual animals should be 6 x 8 feet or larger.

Shade: Provide natural shade in hot weather and insulate all buildings overhead. (R factor of 12 is adequate).

Water: Provide automatic watering facilities. These decrease amounts of water used.

Feed: Provide facilities that will permit limited feeding, or set up for every third day feeding program. Allow 15 to 18 inches of feeder space per sow.

Ventilation: Provide natural ventilation.

Lighting: Use natural lighting such as skylights wherever possible. When using skylights in farrowing houses, precautions must be taken to avoid overheating in the summertime. Use fluorescent light where artificial lighting is required. They give about four times as much light per watt as incandescent bulbs and last up to seven times as long. Wire the facility with multiple switches so that only the necessary lights need be turned on at one time.

Farrow-to-Finish House

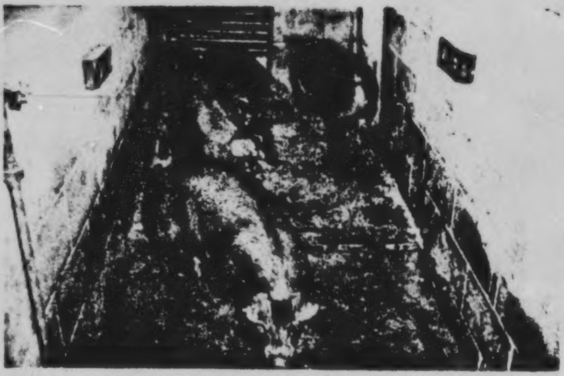
There is some interest in farrow-to-finish houses which may be practicable for some situations. In this type of building, the pigs are farrowed in one area and remain there until marketed. The sows are moved at weaning time.

Advantages:

1. Less stress on pigs due to moving.
2. Pigs are raised with litter mates which helps prevent fighting.
3. Easier to make full use of and to schedule building use.
4. Generally all pigs are the same age in the building. A vacant period can be provided between farrowing.
5. Disease and sanitation control is simplified.
6. Fewer clean-ups needed due to moving pigs.

Disadvantages:

1. Marketing from a building would be done twice each year. If greater frequency is desired, additional buildings would need to be built.



Pigs at Florida Swine Evaluation Center.

2. Check the investment cost per pig carefully as compared to a multiple house system -- it may be more. With detailed planning, it need not cost more.
3. Designing the size and shape of pen to fit both farrowing and finishing requirements needs careful study.
4. Equipment used must be portable so that when it is needed for farrowing, it can be easily removed and replaced by equipment needed for growing and finishing.
5. Design of heating and ventilating equipment to fit all stages of growth needs careful study.

LAGOONS

As for waste disposal, lagoons seem to be the answer in most situations. Very few problems are observed if the lagoons are properly designed although many do not have sufficient volume. A person contemplating the construction of a lagoon should obtain a permit through the Soil Conservation Service. Your local County Extension Director can advise you on how to obtain the help you need. (See Figure 2)

BREEDING

Half the success of a swine breeding program depends on the herd sire. The fact that a boar looks good or is well pedigreed is no guarantee that he will sire the type of animals that are desired. It is wise to progeny test a prospective herd sire by breeding him to three or four sows and testing the offspring under the same environmental conditions and management practices before going "wholehog" in his use as a herd sire.

Although this can be done privately, progeny testing in Florida is systematically researched at the Florida Swine Evaluation Center. By entering a test group of four pigs by one sire, weighing 30 pounds or more, not over 80 days of age and out of at least two litters, valuable information can be obtained. Pigs are tested for the following traits: feed efficiency; rate of gain; carcass evaluation; carcass health; parasite count; and pig index score.

It is beneficial to test the performance of your boars by some means and to compare breeding programs with other producers in the state.

Other breeding practices that pay-off in swine production include the following:

1. Breed gilts in their third heat period, usually six to eight months of age. Breed gilts on the first day heat is observed. Re-breed 12-24 hours later.
2. Sows can be bred in the post-weaning heat, if pigs are weaned at five weeks of age or older. If earlier weaning is practiced, wait until the second heat to breed. Breed sows on the second day of heat and again in 12-24 hours. Breeding in the post-farrowing heat is not recommended.
3. Hand mating is preferred over letting the boar run with the herd. If a boar is to service more than one female, breeding should be at least four hours apart. If pasture breeding is used, rotate boars so they do not become overworked. A young boar should run with no more than 10 gilts and older boars should run with 15 or less.
4. Flushing by higher feeding levels at breeding time will increase litter size if feed was properly restricted prior to the flushing period. Start flushing one to two weeks before breeding and continue for one day after breeding. Cut feed back to four and one-half pounds on sows and five pounds on gilts. Feed a 14-16 percent balanced ration.
5. Use a safe wormer to treat for internal parasites prior to breeding. Spray animals with a recommended insecticide to control lice and mange before breeding.
6. Record breeding dates to plan for farrowing time management.

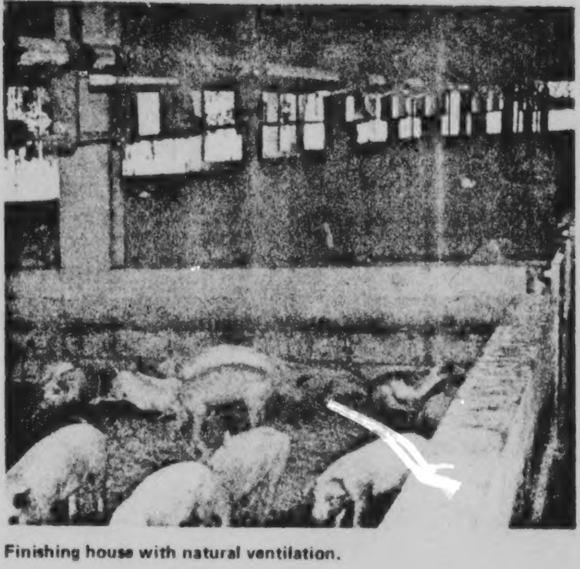
CARE OF YOUNG PIGS

Studies have shown that approximately 30 percent of all live pigs farrowed die before they are eight weeks old. Some major causes of death are crushing by the sow, chilling, starvation, scours and other diseases.

Using farrowing stalls or pens aids in reducing the number of pigs crushed by the sow. This number may also be decreased by culling fat sows or sows with inverted nipples and those that are careless of the way they move among their pigs.

It is during the first week that 50 percent of the deaths occur. Paying closer attention to the litter at this time can reduce losses. Pigs that are weak at birth should be given special treatment since they would be the most likely to be crushed.

Death due to chilling usually occurs during the first few days after farrowing, because the temperature regulating mechanism of the pig does not start to function until it is two days old. In cold weather heat lamps, pig brooders, or heated floors are essential. It was found that pigs up to six to seven weeks of age do well at temperatures of 85-92 degrees, whereas those kept at 65-70 degrees did not perform satisfactorily. In addition to supplying artificial heat and draft protection, bedding, when used, should be changed regularly.



Finishing house with natural ventilation.

Feeding young pigs can reduce the mortality rate. For the first few weeks of life sows milk is the only source of food. If there are more pigs than the sow has udders, the weakest pigs will get left out at meal time. Try to even up the number of pigs and udders by switching pigs around. A sow will usually accept another sow's pig eventually. You can also use one sow for the weak or small pigs from all litters. Or a prestarter can be fed to the weaker pigs.

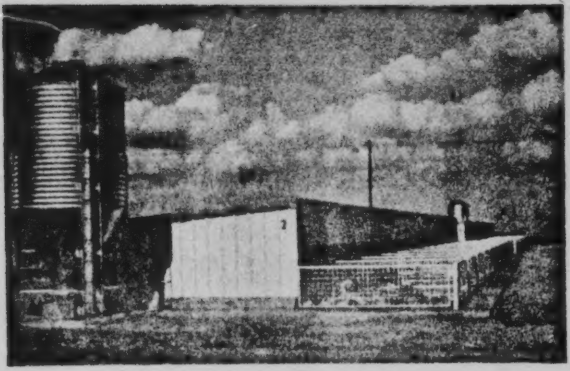
Creep feed should be available to all pigs at three weeks of age when the sows milk production starts to decline. By six weeks of age the pig is almost entirely dependent upon the feed you provide.

Pigs are born with a low supply of iron, creating the threat of anemia. To combat this, pigs should be administered iron either by injection or oral methods at three to five days of age and again at 21 days. Even though injectable compounds are more expensive initially, the time and labor involved in the oral methods make iron injections less costly in the long run.

Other practices to aid in the thriftiness of young pigs include the following:

1. Clip needle teeth shortly after birth. Clip only the tip. Avoid crushing the teeth.
2. Clip navel cord soon after birth to about two inches then tie off. Treat with iodine solution.
3. Castrate pigs at one to three days of age. They are easier to handle and require less labor.
4. Dock tails at one to three days of age. This will cut down on tail biting in confinement feeding.

Following the above practices should lead to a larger percentage of live pigs at weaning time. Pigs may be weaned



Swine confinement leaves land for food crops.

at three to six weeks of age. By six weeks pigs should weigh around 25-35 pounds. Let the pigs remain in the same quarters until they weigh 50-60 pounds and then move to grower or finishing unit.

FEEDING PRACTICES

In swine production there is no one best set of rations. This is due to the wide differences in cost of grain and protein supplements in different areas, feed processing costs, herd health, quality and cost of labor, meatiness of herd and the pricing system of market hogs. Your local County Extension Director could suggest rations to fit your situation.

As corn prices rise, producers have discovered that sorghum grain is an excellent feed for swine when fed correctly and properly supplemented. Sorghum grain-fed hogs gain as rapidly as corn-fed hogs but usually require 10 to 15 percent more feed to produce 100 pounds of gain. Carcasses from sorghum grain-fed pigs are equal to corn-fed pigs in yield, finish, firmness and grade.

Sorghum grain, like corn, is an energy feed. When considering the nutrient requirements of pigs, it is low in total protein and deficient in several amino acids, vitamins and minerals. Thus, sorghum grain must be supplemented when fed to pigs. Pigs, weaned early when they are three to six weeks old, do not do as well on sorghum grain as on corn.

DISEASE CONTROL

It is extremely important for the swine producer to be aware of the potential disease hazards that can affect swine. Proper feeding and sanitation practices can decrease the danger of disease in swine, but care should be taken in other areas to guard against disease and parasite infection.

Vaccinate for contagious diseases prevalent in your area as recommended by a local veterinarian. Vaccinate once or twice a year for erysipelas. If this disease is a problem in young pigs, vaccinate during pregnancy. Vaccinate the young pigs for erysipelas between six and 12 weeks of age. For leptospirosis, vaccinate prior to breeding or during the first third of pregnancy. If the disease is a problem, repeat vaccinations every six months and feed a selected antibiotic the last half of gestation until the infection is eliminated from the herd. Where this disease exists, inject young pigs at 10 weeks of age.

Here are some rules that should be followed to reduce the chances of spreading disease:

1. Buy animals from herds whose health status in known. Move animals in properly cleaned and disinfected trucks. Isolate new animals for 30 days. Wash new animals in a mild disinfectant prior to admitting them to the herd.
2. Test breeding stock annually for brucellosis and leptospirosis. Deworm breeding stock regularly (twice per year).
3. Avoid stress on animals. Stress can be caused by overcrowding, improper ventilation, inadequate manure removal, improper nutrition and parasite control.
4. Avoid outside traffic in areas of swine production. Change clothing after visiting neighboring farms or auctions where disease may be prevalent.
5. Diagnose disease promptly. Isolate sick animals from healthy ones. After a complete autopsy dispose of dead animals by burning, deep burial or through rendering companies. Disinfect contaminated facilities and allow them to lie idle for two to three weeks befor use.

CONCLUSION

Mismanagement of swine producing operations causes waste of time, labor, money and food energy to man. If tight management practices are followed, more profits will accrue to the producer and energy will be conserved as a by-product.

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IS-SE-10.0:278

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West Virginia University and U. S. Department of Agriculture Cooperating.

STUDENT COMPETENCY SHEET

Module 2: Energy Conservation in Livestock and Poultry Production

Competency 3: Produce beef with minimum energy expenditure

Introduction:

The beef cow is a relatively energy-efficient critter. Given the opportunity, she will harvest and process her own feed. And during the winter, she can survive on low-grade roughages (with a bit of protein supplement) which are energy-efficient to produce and to feed.

Although you can probably spot a few methods of saving energy in managing a beef herd (for example--reducing pickup usage, feeding supplement on alternate days, shortening the calving season), your greatest possibility for energy efficiency will be to produce more pounds of beef without using additional energy.

Resources and Equipment:

WVU Extension Circular SE-9.0, Energy Conservation in Beef Cattle Production.

Learning Activities:

1. Read WVU Extension Circular SE-9.0, Energy Conservation in Beef Cattle Production. Note that production efficiency and energy conservation go hand in hand.

2. Answer the following questions:

   a. How does nutritional level of the beef herd influence energy consumption?

   b. Why are large round bales considered more energy-efficient than small bales? Compare custom rates per ton of hay baled with large vs. small bales. (Contact custom operators for rates.)

   c. Compare methods and energy efficiency involved in feeding large round bales in the field as contrasted with hauling them to the barnlot for feeding. Discuss with your teacher and classmates.

   d. How can the beef cattle producer conserve energy in liming and fertilizing pastures?

   e. Is it beneficial to worm the beef cow herd in West Virginia? If so, what material is used and when is it done? (Discuss with your teacher.)

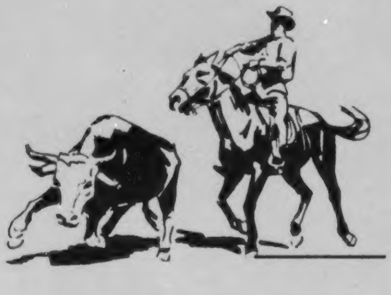
   f. What is the most energy efficient method of controlling lice and flies on beef cattle? What material is used?

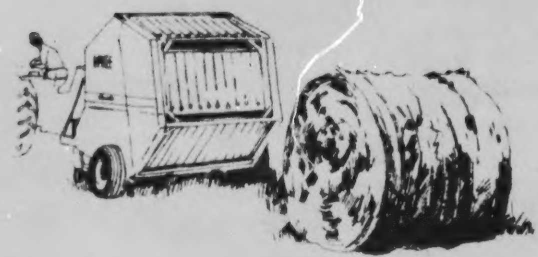
   g. How can an extended grazing period in the fall influence energy consumption? How can the grazing period be extended?

3. On a field trip, analyze the beef cattle operation on your farm or that of a farmer in the community. Identify at least ten practices that would improve energy efficiency in the operation.

Evaluation:

1. Turn in your answers to Learning Activity #2.
2. Following the field trip (Learning Activity #3), present the potential energy conservation practices you identified to the class.





SE-9.0

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SOIL & WATER
FOOD ENGINEERING
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ELECTRIC POWER & PROCESSING
STRUCTURES & ENVIRONMENT

Agricultural
Engineering

energy conservation in beef cattle production

The current energy crisis affects all areas of agriculture both directly and indirectly. As fuel and energy resources diminish, agricultural operating costs rise. There are areas in beef cattle production in which efficiency can be increased. Thus, the demand on energy supplies is reduced and the cattleman realizes a greater profit. Closer management of beef cattle operations is the key to energy conservation.

NUTRITION AND FEEDING PRACTICES

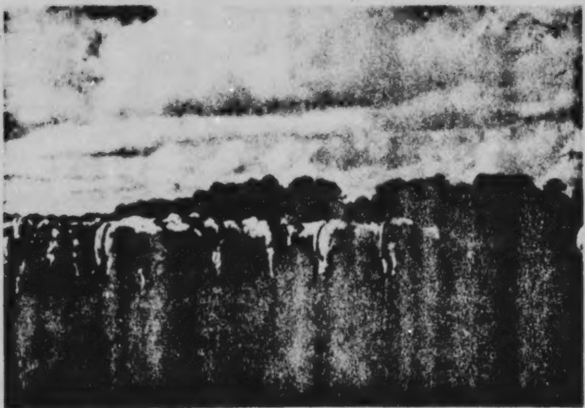
Proper nutrition is essential for an efficient, productive beef cattle herd. Depriving cattle of feed does not save money in the long run because of slow growth and weight loss suffered by the cattle. Reproductive efficiency, milk production, meat quality and overall thriftiness are reduced by poor feeding practices. Animals receiving a poor level of nutrition are also more susceptible to disease.

When pasture areas are not large enough or sufficiently productive, cattle must be supplemented with feed and hay. To best meet the needs of a particular herd, the cattleman should discuss his circumstances with his agricultural Extension agent or a trustworthy feed supplier.

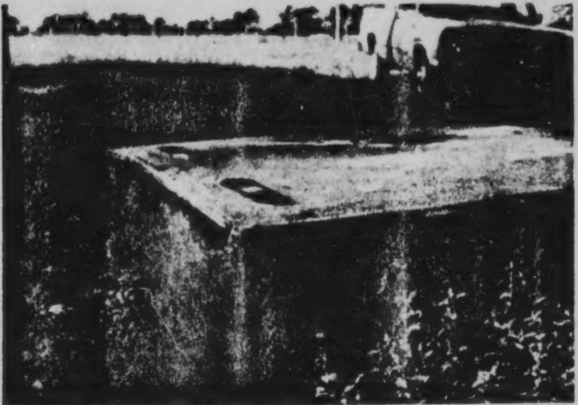
When feeding concentrates, the use of self-feeders will assist the rancher in conserving energy. Feed can be delivered in bulk to a self-feeder once or twice a week. Cattlemen can usually get a cost break on bulk feed because the expense of bagging the feed is eliminated. Handling bagged feed on the farm is time consuming and requires labor and equipment to put out. Bagged feed must also be distributed more frequently than bulk feed.

By-product feeds should be used as much as possible. In a state such as Florida, there is a high availability of by-product feeds such as citrus pulp, citrus molasses and blackstrap molasses. These by-products can be fed as they are and do not require mixing or processing. They can also be delivered in bulk and are usually relatively inexpensive. By utilizing by-products as a feed source, cattlemen conserve other types of feed that are more costly, and require energy to produce.

In addition to pasture, it is usually necessary to supplement winter feeding with hay to supply adequate roughage for cattle. When harvesting hay for cattle it is recommended to use large round hay bales instead of small individual bales. It takes consider-



Closer management of beef cattle operations is the key to energy conservation.



Self-feeders save time, labor and energy.

Feed large round hay bales for energy savings.

ably less energy to harvest, store and feed the large round bales weighing from 1000 to 1400 pounds. Even though special equipment is necessary to handle the large bales, there is an appreciable savings on bailing twine as well as labor. Large bales do not have to be put out as frequently and they shed rain better than small bales. If fed properly, there is less waste and loss of digestible nutrients with larger bales.

PASTURE MANAGEMENT

Getting the most out of your pastures is extremely important for efficiency in beef cattle production. The most fertile areas should be carefully managed and used intensively. These areas should be crossfenced and the cattle rotated. When possible, it is desirable to grow legumes in these more fertile pasturelands. The best fields are usually reserved for cows with calves. Pregnant cows and replacement heifers are usually pastured on the less fertile areas until they calve.

To increase production of pasture it is advisable to fertilize. In the interest of energy conservation as well as the reduction of costs, cattlemen are urged to purchase fertilizer in bulk. It is cheaper to purchase fertilizer in bulk and have it custom spread than for the rancher to handle individual bags, using his own trucks and tractors. Since pastures should not all be fertilized at the same time, the use of custom operators saves the rancher time, fuel, and wear on his own equipment.

Since some commercial fertilizers are petroleum derivatives, supplies are becoming more costly. For these reasons it is necessary for the rancher to determine the exact amounts of fertilizer needed for optimum pasture production. Do not over fertilize. The county Extension agent can supply information to help determine the amounts of fertilizer needed.

HERD HEALTH

When cattle are fed properly, disease and parasite problems are minimal. However, it is still a good practice to have a beef herd on a regular health care schedule. In many areas it is necessary to worm cattle at least once a year. Sick cows should be separated and placed in a confined area in order to receive additional attention.

When possible, oilers and backrubbers should be used to control external parasites such as flies and lice. If properly placed in a pasture, oilers and backrubbers can save a considerable amount of time, labor and expense. They eliminate the need to drive cattle to pens and use mechanical equipment such as sprayers or foggers.

BREEDING MANAGEMENT

Controlling the breeding season of a beef cattle herd is another management practice that saves time and energy for the cattle rancher. Bulls should be allowed to run with the cows beginning February 15, depending on the area of the state. Bulls should be with cows for no longer than 90 days. During this time 80 percent of the cows that are going to conceive will do so during the first two heat periods. Those cows that do not conceive during this time should be eliminated from the herd.

Calves are born approximately 273 days after conception. When a controlled breeding season is used, the calves will all be born at about the same time within a three month period. At approximately four to six months of age the calves should be worked. This means vaccinating all calves for black leg and malignant edema, castrating the bull calves, dehorning the replacement heifers, as well as branding any calves the rancher wants to identify later. When a controlled breeding season is used, all calves can be worked at the same time. This eliminates unneces-

Oilers and backrubbers control external parasites.

sary equipment usage, time and labor. Using this practice, calves can also be weaned and marketed in one group.

When calves are weaned in the fall, all cows should be checked for pregnancy. Those cows that are open (not bred) should be sold at this time because it will be at least two years before they will produce a marketable calf. Selling open cows will conserve the feed they would consume in two years as well as fuel, time and labor necessary in handling them in that period.

Before bulls are put with the cows for breeding they should be tested for fertility and disease. Infertile, crippled or diseased bulls should be sold as should bulls with bad eyes.

CONCLUSION

Cattlemen should consider implementing the above practices and keep energy conservation in mind in all areas of their operations. It has been found that when energy is conserved, so is time and labor, making for a more profitable operation.

STUDENT COMPETENCY SHEET

Module 2: Energy Conservation in Livestock and Poultry Production

Competency 4: Produce poultry and eggs with minimum energy expenditure

Introduction:

According to USDA reports, 71 percent of the direct energy consumption in poultry production is used in brooding. If one is to conserve energy, the smart thing to do is to go after the big user first. Further energy efficiency in poultry production will likely be most easily found in reducing feed consumption while maintaining or increasing production of meat and eggs--that means tightening up on management practices.

Resources and Equipment:

WVU Extension Circular SE-11.0, Energy Conservation in Chick Brooding.

A poultry or animal science textbook (e.g., Livestock and Poultry Production by Bundy and Diggins).

Learning Activities:

1. Read WVU Extension Circular SE-11.0, Energy Conservation in Chick Brooding. Be able to:

   a. Explain the concept of partial house brooding as an energy conservation measure.

   b. Explain how the poultry producer can be assured of adequate ventilation during partial house brooding.

   c. Name at least five other ways to save energy in brooding.

2. In another reference (e.g., Ch. 31, Livestock and Poultry Production), read the section on feeding and management of the laying flock OR feeding and management of broilers, depending on your interests.

   Identify at least ten management practices that will help to maximize egg or meat production with the least possible direct and indirect energy inputs (feed, fuel, equipment, electricity, etc.).

3. On a field trip to your own poultry operation or one in your community, analyze the operation and identify at least five management practices, not currently being used, that will directly or indirectly conserve energy.

Evaluation:

1. On a written examination, you will be able to explain how partial house brooding works, how to provide adequate ventilation during partial house brooding, and name five other ways to save energy during brooding.

2. Turn in your list of management practices from Learning Activity #2.

3. In a class discussion following the field trip (Learning Activity #3), you will discuss the five management practices you identified that will conserve energy.

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Agricultural
Engineering

energy conservation in chick brooding

Energy costs and adequate fuel supplies are of growing concern for poultrymen since energy plays an important role in the operation of their poultry houses. Although there are several concerns related to energy in efficient poultry management, this fact sheet focuses upon energy conservation as it applies to chick brooding.

For poultry management practices to be feasible, they must be economically beneficial. The methods discussed in this fact sheet may not be economically justified for some poultrymen at present. However, they may be worthwhile in the future, if and when feed and/or fuel become increasingly costly—a very real possibility because of the inevitable depletion of our nation's fossil fuel resources.

Since oil does not burn as hot or as clean as LP gas, the vast majority of brooders are designed to use LP gas. Fuel for brooding represents about 6-8 percent of the poultryman's cost of growing broilers. About 75-80 percent of the heat is used during the first two weeks of brooding. Therefore, if a reduction in fuel could be realized during this period, the poultryman would derive substantial savings in total fuel consumption.

PARTIAL HOUSE BROODING

Partial house or small-area chick brooding is one means of reducing fuel consumption. Most of the research and application of this method has been in the area of broiler production, but partial house brooding should be applicable to egg-type pullet chicks as well as broiler chicks.

How It Works

Partial house brooding is accomplished by installing a polyethylene curtain from ceiling to floor at one end or portion of the house to make a brooding area of 15-30 percent of the brooder house. All chicks are brooded in this portion for the first two weeks. The poultryman adjusts the polyethylene curtain up or down to maintain proper temperature.

After the first two weeks, the polyethylene curtain is moved to the middle of the house to make a brooding area of one-half of the house for the next two or three weeks. Thereafter, the entire house is used (see Figure 1). Depending on outside temperature, the brooders may be turned off after this five or six week period.

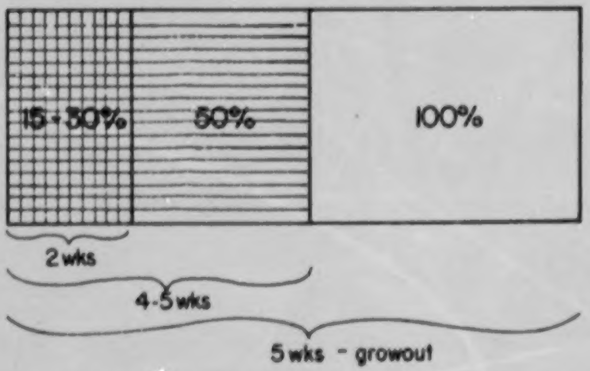

Figure 1. Partitioning Of House Over Brooding Period For Partial House Brooding.

USDA researchers in Mississippi were able to reduce fuel consumption from 90 to 30.5 gallons per 1,000 broilers by using partial house brooding. They restricted the birds to 15 percent of the house for the first two weeks and to 50 percent of the house for the next two weeks. Mortality was 1.5 percent and feed per pound of live weight was 2.01 pounds.[1] Satisfactory results and fuel savings have also been reported by commercial broiler producers using varieties of partial house brooding.

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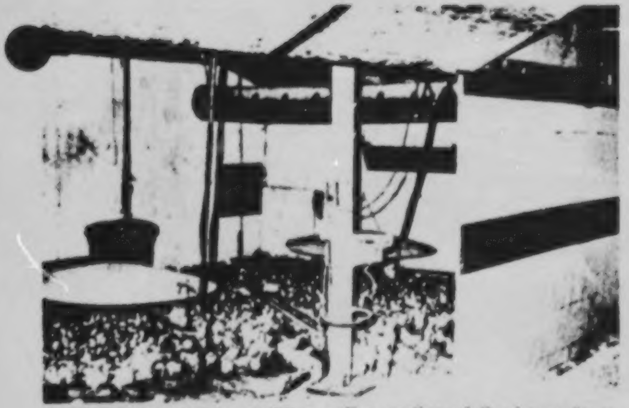


A polyethylene curtain partitions off a portion of the house to reduce brooding area.

Ventilation

One important aspect of partial house brooding is proper ventilation, which requires houses to be equipped with ventilating fans to remove accumulated carbon dioxide, ammonia and moisture. During the first two weeks, .15 to .20 cubic feet of air per minute per bird is necessary to remove gases and moisture (to prevent wet litter).

Since many houses in warm climates such as Florida may not be equipped with fans, partial house brooding may not be practical for these at present. However, as fuel and feed costs increase, the economics involved may make house modifications profitable in the long run.

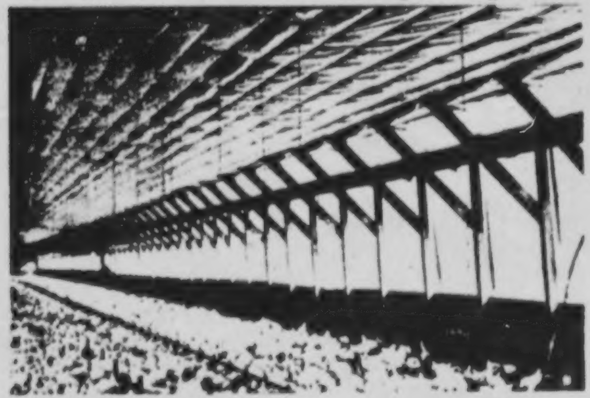
ENERGY SAVING TIPS

Generally, good management will result in energy savings as well as lower operational costs. If energy costs continue to rise, certain management practices which may be questionable now will become economically feasible. The following suggestions are just a few of many possible ways to conserve energy while brooding chicks. Your awareness of the necessity of conserving energy will lead you to other ways to reduce energy consumption while improving the management of your brooding activities.

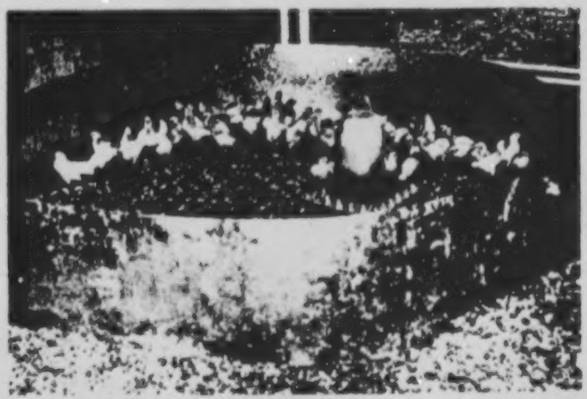
Energy savings tips useful for all chick brooding:

1. Check and adjust brooders to insure proper operation before starting to brood.
2. Check thermostats regularly, since a defective thermostat can waste fuel.
3. Insulate the house roof to reduce heat loss.
4. Use only dry litter material and maintain enough ventilation to keep it dry.
5. Prevent water spillage to help keep litter dry. This is an effective means of disease protection as well as a way to decrease the amount of time you must operate your fans.
6. Use brooder guards of solid material, such as corrugated paper or sheet metal.
7. Brood the maximum number of chicks that each brooder can handle, according to the manufacturer's recommendations. Brooding more chicks than is recommmended for the unit requires especially conscientious management.
8. Increase brooder capacity by enclosing three or four brooders in one brooder guard.
9. Keep chicks comfortable, but not hot.

For further information, contact your County Extension Office.



Insulate the roof to reduce heat loss.



Use a brooder guard of solid material.

Arthur W. Selders

Arthur W. Selders, PE
Extension Specialist
Agricultural Engineering

STUDENT COMPETENCY SHEET

Module 2: Energy Conservation in Livestock and Poultry Production

Competency 5: Produce lamb and wool with minimum energy expenditure

Resources and Equipment:

Animal science textbook

Learning Activities:

1. The ewe that loses her lamb(s) has cost a year's feed and care. Feed, indirectly, consumes the greatest amount of energy in producing sheep. The year's feed bill is lost, and the potential profit is lost, if lambs fail to survive. Using available references (e.g., Livestock and Poultry Production by Bundy and Diggins), identify eight practices that can help to save every lamb born.

2. The greatest deterrent to feed efficiency (and health) in sheep production is parasites. Using available references, outline a parasite control program for your flock or for a sheep producer in your community.

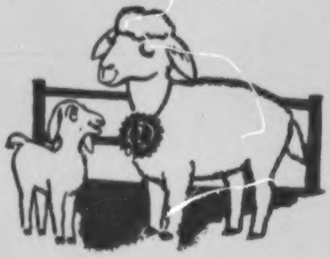
3. From your observations, experiences and study, identify five operations or techniques in sheep production that are direct consumers of energy (electricity or fuel). Suggest ways to reduce energy consumption in each of these areas.

4. On a field trip to your own sheep operation or one in your community, analyze management practices used and identify at least five practices that will either conserve energy or will increase production with no increase in energy (including feed) consumption.

Evaluation:

1. Turn in your written assignments for Learning Activities 1, 2 and 3. Your instructor will return them for use in Learning Activity #4.

2. Following the field trip (Learning Activity #4), present to your class the observations you made with regard to direct and indirect methods of energy conservation in sheep production.



STUDENT COMPETENCY SHEET

Module 3: Energy Conservation in Farm Lighting

Competency: Reduce energy consumed in farm lighting

Introduction:

Cost of operating electric lights is determined by wattage of the bulbs and hours of operation. Your electric bill is based on the Kwh (Kilowatt hours) of electricity used. A Kwh is equivalent to 1,000 watts used for 1 hour. A 100 watt bulb which burns for 10 hours would use 1 Kwh of electricity (100 w. X 10 hrs. = 1,000 watt hours or 1 Kwh).

The power company charges about 6¢ per Kwh used (in 1982). At this rate, it will cost you 6¢ to use a 100 watt bulb for 10 hours. If you count the lights around a farmstead, you can understand why electricity is a major expense in many operations. Information in this lesson will help you to understand how you can reduce your electric lighting bill.

Resources and Equipment:

NRAES Publication FS-27, Efficient Lighting for Farms.

Learning Activities:

1. Read NRAES Publication FS-27, Efficient Lighting for Farms. Complete the following:

   a. What is meant by the term "lumen"?

   b. How is efficiency of an electrical light measured?

   c. What are five ways to reduce lighting costs on farms?

   d. Fill in the table:

	Bulb cost	Appx. lumens per watt	Ave. life, hours	Advantages	Disadvantages
100 w. Incandescent					
40 w. Fluorescent					
100 w. Mercury Vapor					

2. On a field trip, observe lighting in use in a tie-stall dairy barn, a poultry laying operation, or an area of your school (e.g., the agricultural mechanics laboratory). Using information in NRAES Publication FS-27 and other sources, suggest alternative lighting methods and estimate as accurately as possible the savings that could be realized by the changes you suggest.

Evaluation:

1. Turn in your answers to Learning Activity #1.

2. Prepare and turn in a written report of suggested changes and anticipated savings for Learning Activity #2.

NRAES

Efficient Lighting for Farms

All farms, whether dairy or poultry, existing or being planned, use lights. Efficient lighting or different programs that use existing lights offer a real potential for saving money without sacrificing production or operator comfort.

LIGHTING EFFICIENCY

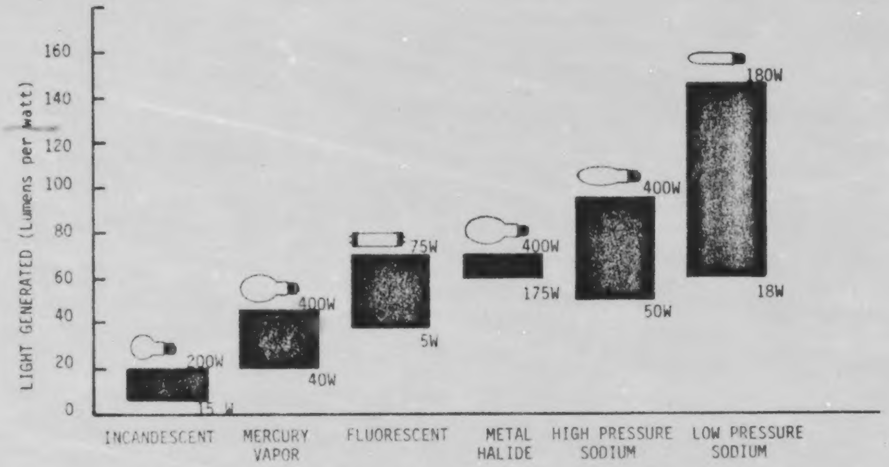
Lighting efficiency is getting the most light for the electricity you buy. The watt is the measure of the rate of electrical flow and is directly related to the kilowatt-hours (kwh) you pay for on your utility bill. The **lumen** is the measure of light output from a lamp. Efficiency of a lamp is measured in lumens per watt (lm/w), or the amount of light a lamp puts out for each watt of electricity it uses.

Table 1 lists some lamps available and their approximate efficiency. In general, the most efficient lamp should be used to provide the most light for the dollar. However, each lamp has different characteristics which may limit its use in certain conditions.

Incandescent

Incandescent bulbs are the most common; they are inexpensive to purchase and readily available. They are interchangeable (a 100-watt bulb can be replaced by a 25-watt bulb); so light intensity may be changed without changing the fixture. Incandescent bulbs are very inefficient and dissipate much energy as heat rather than converting it to light. Because of this they can cost much more to operate than some of the more efficient types of lighting.

Figure 1. Efficiency of typical electrical lamps.



	Watts	Approximate Average Lumens	Approximate Lumens/Watt[1]	Average Life
Incandescent	15	144	9	1,200
	25	225	9	1,000
	40	460	11	1,000
	60	850	14	1,000
	75	1,170	15	750
	100	1,600	16	750
	150	2,500	17	750
	200	3,500	18	750
Fluorescent	15	675	34	7,500
	20	1,200	40	9,000
	40	3,200	50	20,000
	75	5,500	70	
Mercury Vapor	75	2,800	40	16,000
	100	3,800	40	16,000
	175	7,500	40	24,000
	250	11,600	45	24,000
	400	21,000	50	24,000
Metal Halide	175	12,000	65	7,500
	250	17,100	69	10,000
	400	34,000	80	20,000
High Pressure Sodium	70	5,200	65	20,000
	100	8,500	74	24,000
	150	14,400	83	24,000
	250	24,700	86	24,000
	400	45,000	98	24,000

[1] Includes ballast losses where appropriate

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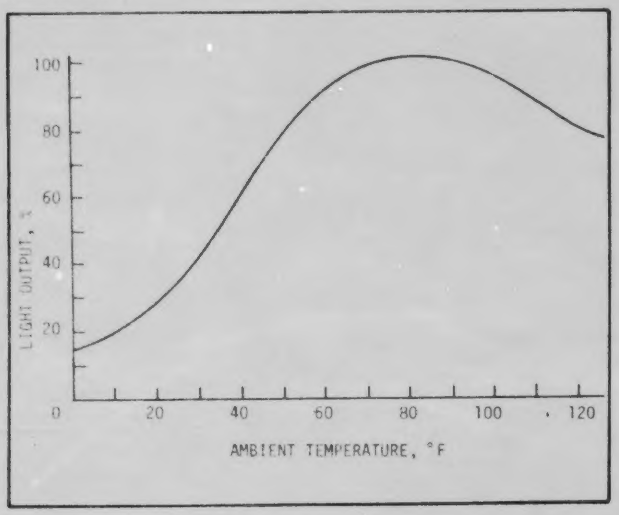
Fluorescent

Fluorescent lamps provide approximately **four times the light of incandescents** per watt (or per dollar) of electricity used. Fluorescent tubes also last much longer than incandescents; for instance a single 40-watt, rapid start fluorescent can outlast twenty or more 100-watt incandescent bulbs. However, standard fluorescents start unreliably below 50°F and their light output decreases approximately 1% for every degree below 65°F. These factors limit their use to warm barns or other relatively warm locations. They are available in a variety of types and sizes, including special outdoor fixtures and screw in replacements for incandescents.

Figure 2. Light output vs. ambient temperature for 40w fluorescent.



High Intensity Discharge (HID)

High Intensity Discharge lamps are efficient producers of very bright light. They have no problems starting or operating in cold weather. However, they generally require mounting heights of 10 to 20 feet to make use of their intense light. Another disadvantage is that they require one to ten minutes of warming time to reach full output, and, if shut off, they need an additional one to five minutes to cool before they will restart.

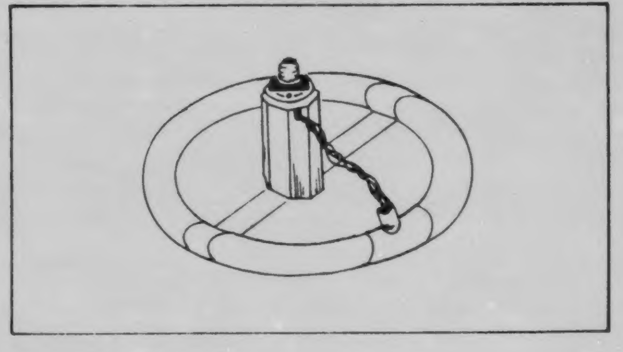
Mercury Vapor lamps are the most readily available and the least expensive of the HID lamps. They supply more than twice as much light per watt as incandescents and with a life exceeding that of fluoresents. The lamps are available in either the standard clear globes, which have poor color renderings or phosphor coated globes which yield a light suitable for certain indoor uses.

Metal halide lamps provide the whitest light of the HID lamps. They are useful for areas where color rendering and appearance are important. They are approximately four times more efficient than incandescents. These lamps are initially more expensive and have a shorter life than Mercury Vapor.

High Pressure Sodium lamps are the most efficient of the three readily available HID lamps, yielding greater than five times more light output per watt than incandescents. These lamps produce a yellow light, though special ones are available which produce a much whiter light. High pressure sodium lamps are the most expensive of the three readily available HID lamps, but because of their high efficiency (five times that of incandescents) they are the cheapest to run. They are also available as replacements for existing lamp fixtures, such as mercury vapor. These replacements are very specific and must only be used with certain ballasts and in high voltage screw sockets.

Another type of HID lamp is the low pressure sodium type. These lamps are expensive, not readily available, and produce a golden to orange light with poor color rendering properties. However, they are very efficient providing from 80 to over 150 lumens per watt.

Figure 3. Self contained screw-in fluorescent utilizing circline type lamp.



WAYS TO SAVE

Reduced Lighting Use

Of course, the best device for decreasing light use and saving money is the light switch, but there are many other ways to save. In some instances an area may be overlit allowing certain lamps to be removed or lower wattage bulbs to be substituted. When modifying the light output of a fluorescent lighting system remember that the ballast draws energy even with the lamps removed, and removal of one tube in a two lamp fixture may cause the other to stop working.

Fluorescent alternatives include using a dummy tube which produces no light; energy saving tubes that only produce a slight decrease in light but decrease energy use by about 15% (amounting to a savings of around $7 over the life of each tube); or energy saving tubes that may work either in pairs or with a standard tube to cut light output and energy consumption by 50% to 88%.

Photo-electric switches can turn outside security lights off at dawn and on at dusk. A single 150 w security light left on 24 hours can cost $46 more to operate in one year than the same light operated by a photo-electric switch.

Poultry lighting

Poultry laying operations present unique opportunities for savings. A first thought might be to replace existing incandescent lamps with fluorescents or HID lamps. These sources may be utilized in the future, but low ceiling height, expensive dimming systems, and lack of experience make their use uncertain. The current lighting recommendation is 0.5 footcandles at the feed trough of the lowest or darkest cages. Higher levels of illumination do not increase egg production, but do increase cannibalism and electrical cost. Thus incandescent lamps with a solid-state dimming device are still the recommended type of lighting.

Interrupted night lighting programs use shorter periods of light interspersed with periods of dark to reduce energy consumption without sacrificing production or egg size. Testing of interrupted night lighting has shown the 8 hours of light—10 hours of dark—2 hours of light—4 hours of dark (8L-10D-2L-4D) and the 2L-12D-2L-8D lighting programs to yield egg production results equal to the standard 16L-8D or 14L-10D programs. Interrupted night lighting requires no capital expenditure since most timers presently in use can be adjusted to provide it.

Table 2 shows that savings of $1163 per year is possible using the 2L-12D-2L-8D lighting program as compared to the 16L-8D program. Interrupted night lighting requires light-tight houses and must be started with the onset of the laying cycle. The 8L-10D-2L-4D program provides a period of 8 hours of light in which to do chores, whereas the 2L-12D-2L-8D program provides only 2 hours of light twice a day in which to do chores.

Table 2. Possible savings using alternate lighting schemes in a 32,000+ bird laying house.

	Standard Lighting		Interrupted Night Lighting	
	16L-8D	14L-10D	8L-10D-2L-4D	2L-12D-2L-8D
Yearly Lighting Costs[1]	$1551	$1357	$969	$ 388
Savings Compared to 16L-8D	--	$194	$582	$1163
Savings Compared to 14L-10D	--	--	$388	$ 969

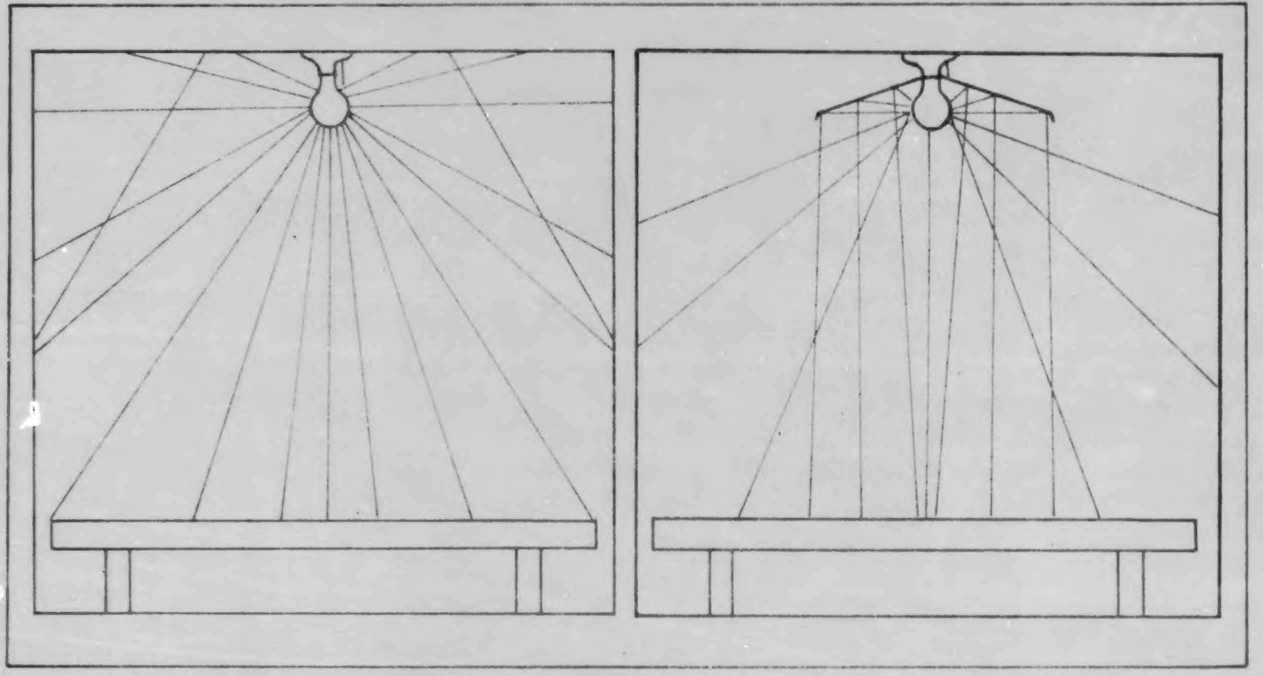
[1] Based on 6¢ per Kwh, incandescent lamps placed 8' on center, supplying approximately 0.5 footcandles at bird level.

ENERGY EFFICIENT LIGHTING

One large incandescent bulb is more efficient than a number of smaller ones. Replacing two 60-watt bulbs with one 100-watt bulb can provide approximately the same light yet save 16% of the energy. Replacing four 25-watt bulbs with one 100 watt bulb will use the same amount of electricity but provide 55% more light. Long-life bulbs are less efficient than standard bulbs of the same wattage and should only be used where replacement is very difficult. For instance, a 75-watt standard bulb will provide as much light as a 100-watt long-life bulb.

Fluorescent lamps can be purchased with energy saving ballasts to provide a 16% energy savings without reducing light output. If the energy saving ballast is used with energy saving tubes, power consumption can be reduced

Figure Reflectors help put light where you want it.



by 25% while reducing light output only 3 to 5%. Based on standard 40-watt fixtures, these two options can result in a savings of $7/tube and $12/tube respectively over the life of the lamp. Also double-lamp fixtures are more efficient, and should be given preference, to two single-lamp fixtures.

Dirty lamps and lenses, a problem with all types of lighting, can reduce light output by 50%. White (or other light high reflectance color) walls and ceilings, and reflectors, can increase lighting efficiency as much as 15 to 20%. (Figure 4).

Substituting existing lighting with more efficient lighting can provide substantial yearly savings. For example, consider an existing 80-cow tie-stall barn presently lit by 36 100-watt incandescent lamps kept on six hours per day. Table 3 shows they cost $473.04 per year to operate. The same amount of light (actually a little more) could be provided by 20 standard 40-watt fluorescent lamps. The fluorescents cost $128.77 per year, a savings of $334.27 per year from the electric bill. A slightly less electrical savings—$264.90—could be made by purchasing circline fluorescents that can screw directly into a regular incandescent lamp socket.

Table 3. Indoor fluorescents vs. incandescents (80 cow tie-stall barn).

Lamp Type	Thirty-six 100w Incandescents	Twenty std. 40w Fluorescent Tubes	Thirty-six 32w Screw in Fluorescents
Light Output (lumens)	61,560	63,000	64,000
Power Cost (6¢/Kwh)	$473.04	$128.77	$208.14
Net savings	--	$344.27	$264.90

Table 4. Outdoor security lighting—HID vs. Incandescents

Lamp Type	4-200w Incandescents	175w Mercury Vapor	100w High Pressure Sodium
No. Lamps	4	2	2
Light Output (lumens)	14,000	14,280	17,100
Power Cost	$175.20	$ 82.34	$ 50.38
Net Savings	--	$ 92.86	$124.82

Outdoor security lighting is another area where savings are possible. Consider a farm with two areas that receive night-time security lighting. Each of these areas are lit with two 200-watt incandescent bulbs burning an average of 10 hours per day, year round. At 6¢/Kwh, this amounts to $175.20 annually as shown in Table 4. If two 175-watt mercury vapor lamps were used instead, it would cost $82.34 per year to operate; a savings of $92.86 per year. If the same lights were replaced with high pressure sodium lamps, it would cost $50.38 per year, a savings of $124.82.

Written by M. D. Tarnoff and R. K. Koelsch, Agricultural Engineering Department, Cornell University

The Northeast Regional Agricultural Engineering Service is an activity of the Cooperative Extension Services of the Northeast Land Grant Universities and the United States Department of Agriculture.

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POULTRY

These hens work on three-quarters less light

Program of 15 minutes light, 45 darkness saves electric dollars; also feed

Over-ride timer switch at house entrance, left, allows lights to remain on longer than 15 minutes if extra chores must be done, Geiger explains.

by JOHN KIMBARK

>Hens have to hustle to eat in Herb Geiger's henhouse.

They've got only 15 minutes during each regular hour of their "lighting day" cycle to eat and drink; the rest of that hour, or 45 minutes, the birds are in total darkness.

It's all part of a "Bio-Mittent" lighting program developed by Ralston Purina Company designed to not only save electrical dollars but feed as well.

Herbert Geiger, who has a laying flock of 31,000 birds on his Northampton County, Pa. farm, was one of the first in the area to try the idea. And, already on his second laying flock with the system, he's more than pleased.

Electrical savings are a big plus, of course.

Lighting a typical 30,000-bird house, for example, means from 200 to 300 light bulbs. Even dimming light intensity with rheostats can mean spinning electric meters during the usual 16 to 17 hours of constant light recommended for hens.

The new 15 minutes on, 45 off program can trim electric bills by a whopping 75%, Purina folks estimate. Or, according to Purina figures on the typical 30,000-bird house, the savings would be $1,260 for the year . . . or 4.2¢ per hen. And that's figuring a kilowatt at only 3.5¢.

But Herb Geiger can tick off some other pluses for the system, too.

"For one thing," he says, "the birds are less mischievous and have less time to get into trouble when they have only 15 minutes of light. They've got to use that time to eat and drink. In other words, they've got to really work."

Less mischievous for the Geiger's, who keep four birds per 12 by 18-inch cage, means there have been fewer cases of birds picking each other or playing with the eggs on the collection belt in front of the cage. Incidence of cracked eggs has gone down; so too has the picking problem.

Herb also notes birds have less time to pick and choose different feed particles from the automatic feeders. They have to eat whatever is there. Hence a more balanced diet.

That brings up another big plus for the system, according to Purina district manager "Ike" Yates, who services the Geiger flock.

"Actually, a savings in feed consumption was one of the reasons the lighting program was developed originally," Yates explains. The idea was to get birds to eat less because of the shorter light period. This since a common problem of laying hens is obesity. In other words, birds can get too fat sitting in a cage all day.

Hens under the lighting program are slimmer, in fact. Purina estimates spent hens coming out of the house after their laying stint weigh about two-tenths of a pound less than their normal light counterparts. The difference is all in waste fat.

Feed savings over the laying year amounts to about 5-6%. Birds not only eat less but require less feed since they save energy and "relax" during their periods of darkness.

Other advantages claimed for the system are a slight reduction in number of cracked eggs; also a little less bird mortality, Yates says.

A possible disadvantage of the system, however, is a small decrease in egg size. Perhaps anywhere from a half pound to a pound less on a typical 30-dozen case could be expected, according to Yates.

Herb Geiger's production record on the first flock through on the new lighting program is impressive enough. The laying year, longer than usual, extended from October 27, 1979 through January 26, 1981. The 31,035 birds housed for the laying stint shelled out:

A total 69.7% eggs average production on a hen day basis or 299.3 eggs per hen;

A feed conversion of 3.71 pounds feed per dozen eggs;

An average 21.5 pounds feed per 100 birds per day for the entire cycle;

A mortality rate of 12.90% over the 15 months in production.

The lighting program isn't for everyone, of course, both Yates and Geiger admit.

For one thing, it adapts best where there is automatic or belt collection of eggs. Otherwise 15 minutes of light during the hour just isn't enough time for hand collecting eggs. That's unless you've got a flashlight tied to your head.

Then, too, it's extremely important that water lines servicing the house have large enough capacity for all birds to drink during that 15 minutes of light. "This lack of water line capacity is probably the biggest single reason for the system to fail," according to Purina's Yates.

> *"Birds also have less time to get into trouble . . .*

And, of course, he adds that feed quality is critical, too. Since less feed is consumed every nutrient counts in balancing up rations.

Egg producer Herb Geiger has also noticed that a few birds probably eat and drink during those periods of darkness. This has helped the less aggressive cage mates meet their full needs, he feels.

Still another advantage comes to light in the dark house. The building is cooler during summer months, Herb has found. This since birds give off less heat during their quiet hours of darkness. And, of course, there is no heat given off by the light bulbs themselves.

Purina estimates temperatures are typically two to three degrees cooler during hot weather than a conventionally-lighted house. So depending on the ventilation system, that also can mean less electric to run fans.

An obvious question, of course, is whether or not birds are affected by extra light length if mechanical failure in the house necessitates burning bulbs longer than the normal 15 minutes.

A longer light period during those emergency lighting periods has no effect, Yates says. Herb Geiger agrees. If he has extra chores in the building he simply over-rides the light timer for a longer period. "But buy only a one-hour override timer," he says. "That way you'll be sure the birds automatically get back on a regular light schedule later."

In fact, Herb admits, every morning his lights are often on longer than 15 minutes during that first "lighting hour" because of extra house chores.

Actually, as Purina explains it, birds under the Bio-Mittent program don't even realize they're in the dark during those blackout periods. A chicken must be in the dark for a set period, usually about 4½ hours, before it is physiologically affected, including egg production. The short periods of light, when repeated in a frequent enough pattern, are interpreted by the hen the same as a constant light.

Geiger believes in low lighting intensity, too. The 200 40-watt bulbs in the house, spaced on 12-foot center over five cage rows, are cut back to the equivalent of 20 to 25 watts through a solid state rheostat. That brings light intensity down to one foot candle at bird level on the bottom cages of his two-deck system. This is enough to "turn on" the birds pituitary gland and thus stimulate egg production.

What does it take to get birds "tuned in" to the reduced lighting system?

The Bio-Mittent lighting program for layers does not begin until pullets are around 36 to 37 weeks of age. Purina has several lighting plans for their pullet grow-out program which vary according to type housing and season of year. But basically the program steps up day length to 17 hours by at least 36 weeks of age.

Then, starting at 37 weeks, 15 minutes of light are removed during each hour segment of the normal 17-hour light day. This is done in one step.

"If egg size isn't up to snuff, or weather is extremely hot, we'll wait a week or two in starting the program," Yates explains. "We want to see at least 65% large or better size eggs."

At 38 weeks of age birds get another 15 minutes of darkness. Or 30 minutes light, 30 minutes darkness.

And at 39 weeks they're jumped onto the 15 minutes light, 45 dark program. They'll remain on this until the end of the laying cycle.

If birds are to be molted for another laying stint the day length is cut back to 8 hours light for a four-week molt period. The 45 minutes off, 15 on program is still continued, however.

At the fifth week of molt birds are jumped to a 13-hour full light day schedule. Lights are then increased 15 minutes each week till a full 17 hours are reached. Then, at peak production, they're changed over again to the Bio-Mittent program.

Poultrymen have been experimenting with various artificial lighting systems for years to turn on hens, of course. But this is probably the most dramatic change in lighting since the Chinese first got the idea centuries ago.

It's our bet we'll see a lot more of it.

STUDENT COMPETENCY SHEET

Module 4: Energy Conservation in Tractor and Farm Engine Operation

Competency 1: Conserve energy through gasoline engine tuneup

Introduction:

Nobody is stupid enough to deliberately pour a can of fuel on the ground each day. Yet, the same waste occurs in operating tractors and engines that need tuned up. The engine that belches smoke or misses on a pull is an obvious candidate for tuneup. But fuel consumption needlessly increases long before these distress signals are noticable.

A regular tuneup schedule, as suggested by the manufacturer, is one of the most effective ways to reduce direct energy consumption and save on fuel costs. An added benefit is the increased power of a properly tuned engine.

Resources and Equipment:

WVU Extension Circular PM-18.2, Tuneups Save Fuel.

Operators or Technical Manuals for each engine serviced.

FOS Engines (John Deere)

Mechanics tools, engine test equipment, dynomometer (if available)

Learning Activities:

1. Read WVU Extension Circular PM-18.2, Tuneups Save Fuel. Answer the following questions:
    a. What components of the gasoline engine most commonly cause increased fuel consumption and loss of power?
    b. Assume your tractor uses three gallons of gasoline per hour and works a ten-hour day. After a tuneup is performed, fuel consumption is reduced 14.5%. How much fuel can be saved per day? What is the value of the fuel savings at today's prices?
2. Observe your teacher demonstrate each of the tuneup procedures. Take notes as he does this.
3. Following directions in the operators manual or technical manual for your gasoline engine or tractor, perform each tuneup step. Be sure to:
    a. Clean, adjust, test and/or replace spark plugs.
    b. Check ignition points and condensor. Replace if necessary.

c. Check ignition timing and adjust if necessary.

d. Clean or replace the air cleaner.

e. Adjust the carburetor.

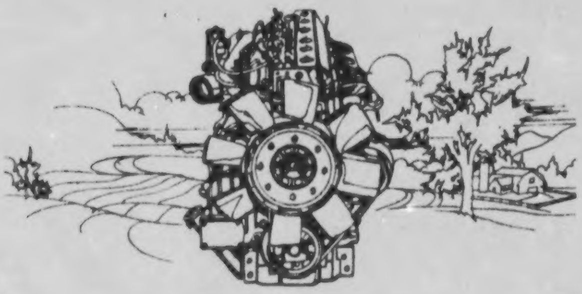
f. Check RPM and adjust the governor if needed.

g. Perform any other procedures called for by the operators manual.

NOTE: If you have access to a dynomometer, test engine performance before and after the tuneup.

Evaluation:

You will perform engine tuneup procedures according to manufacturer's specifications.



COOPERATIVE EXTENSION SERVICE
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tune-ups save fuel

Agricultural Engineering

Farmers in the United States used slightly more than 4 billion gallons of gasoline in 1973. About 47 percent of this amount was used in tractors, 32 percent in farm trucks, and the remainder in combines and other machinery.

Tuning up farm machinery to get the most work possible from every gallon of gasoline has always been a good practice, but the importance of engine tune-ups is even more obvious now because of higher fuel prices and eventual depletion of our fossil fuels. Increasing fuel efficiency by keeping engines tuned offers dollar savings as a short term benefit and also provides more time for scientists to develop alternative fuels needed for the type of farming done in the U.S.

The world is living on an energy savings account which will run out in the forseeable future if the present consumption rate of fossil fuels continues. Energy experts disagree on exactly when our fuel supplies will be exhausted because their opinions differ on how much practically utilizable reserves exist. But all of the experts agree that the supply will be exhausted within a relatively short time unless we develop alternate energy sources.

This fact sheet deals with tune-ups of gasoline engines used in tractors and other farm machinery. Although some suggestions might apply to the operation and maintenance of diesel engines, generally tuning diesel engines requires a greater degree of skill and more specialized tools and equipment. There is a strong trend toward more farm tractors being equipped with diesel engines and more service centers are being built to provide maintenance. Diesels don't require tune-ups as frequently as gasoline engines do, but the tune-up is just as important when it is needed.

SAVINGS POSSIBLE BY TUNING GASOLINE ENGINES

Research studies conducted by agricultural engineers from Kansas State University showed that the fuel consumption of 50 randomly selected farm tractors was reduced by nearly 14.5 percent by tuning them. In addition, the 50 tractors yielded an 11 percent increase in horsepower. This means that a farmer could reduce a 10 hour work day to 9 hours or do 11 percent more work in a normal day's time. In addition to the 15 percent fuel savings the 11 percent increase in horsepower could mean an even greater money savings to farmers in some areas of the United States because the timeliness of certain farming operations greatly influences crop yields.

Two examples of operations that must be performed within a relatively narrow time range if maximum harvests are to be realized are planting corn and harvesting soybeans in the Midwest. Each day of delay in either of these operations reduces yields by about one percent, so an 11 percent increase in horsepower should insure a greater harvest by reducing the time needed to perform these critical operations.

TUNE-UP OPERATIONS THAT CONTRIBUTE TO FUEL ECONOMY

Components of the gasoline engine that most commonly cause increased fuel consumption and loss of power because of improper service are the spark plugs, ignition timing, air cleaner, carburetor adjustment and engine governor.

Fuel consumption decreased 14.2 percent when new plugs were installed.

[illegible]

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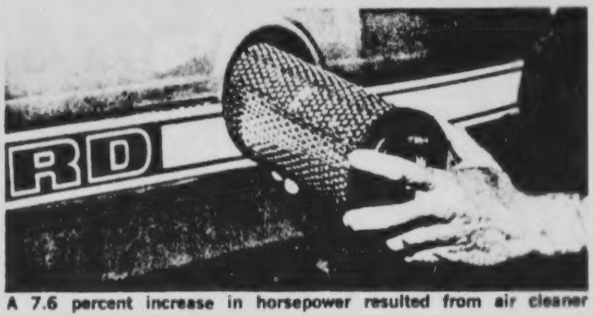
The following summary of research by Kansas State University shows improvements in efficiency realized by various tune-up procedures:

(1) **Ignition timing** was off on 53 percent of the tractors tested. By correcting ignition timing, horsepower increased 5.3 percent and fuel consumption decreased 5.3 percent.

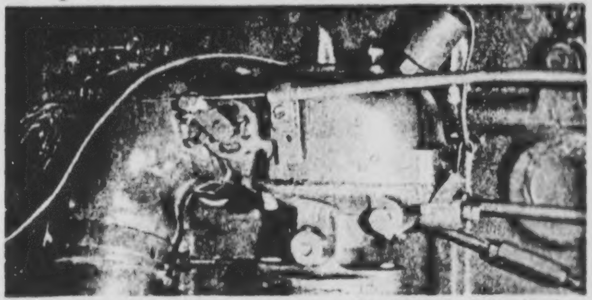
(2) **Spark plugs** were replaced in each tractor unless new plugs had been installed within two weeks preceding the test. Plugs were replaced in 90 percent of the 50 tractors tested. Horsepower increased an average of 5.6 percent and fuel consumption decreased 6.1 percent after spark plugs were installed.

Seven of the tractors tested misfired under load. In all seven cases, misfiring was eliminated by new spark plugs. Power was increased an average of 21.5 percent and fuel consumption decreased 14.2 percent in these seven tractors when new plugs were installed.



A 7.6 percent increase in horsepower resulted from air cleaner servicing.

(3) **Air cleaner** servicing was required on five of the test tractors. This resulted in a 7.6 percent increase in horsepower and a decrease in fuel consumption of 11.4 percent.



Carburetor adjustments were made on 72 percent of the tractors in the study.

(4) **Carburetor adjustments** were made on 72 percent of the tractors with 46 percent having too rich a mixture and 26 percent having too lean a mixture. Correcting the over rich fuel mixture resulted in a 9.5 percent reduction in fuel with no change in horsepower output. Correcting the lean mixture increased horsepower 2.9 percent while increasing fuel consumption 1.4.

(5) **Governor adjustments** were performed on 80 percent of the tractors checked. The no-load speed was too high on 32 percent of the tractors while full-load speed was too low on 62 percent of the tractors. The governor was judged satisfactory if it kept the engine within 20 RPM of the specified speed. Simple repairs and adjustments corrected the governor speeds on only 20 percent of the tractors. This resulted in a 9.1 percent increase in horsepower and a reduction in fuel consumption of 4.8 percent. The remaining 80 percent required replacement of worn governor parts before corrective adjustments could be made.

As pointed out earlier, the overall average result of the above adjustments and replacements was an increase in engine horsepower of 11 percent and a reduction in fuel consumption of 14.5 percent. In 1973, farmers in the United States used about 4 billion gallons of gasoline. Assuming that the nation's tractors could use 14.5 percent less fuel by keeping them better tuned, the potential national savings could be approaching 600,000,000 gallons of gasoline per year. Considering gasoline at .$40 per gallon, the national savings could be $240,000,000.

FOLLOW RECOMMENDATIONS IN OWNER'S MANUAL

Review the operator's manual to determine the service intervals recommended for the particular engine on your equipment. Maintaining good service records makes it easy to plan for future service work.

Most manufacturers recommend regular tune-ups, such as spring and fall or every 500 to 1000 hours of operation. The intervals recommended for some of the tune-up procedures are based on average conditions. An operator must alter the recommended intervals to fit his conditions if they are extremely severe. For example, frequent checking of the precleaner on the air intake system in extremely dusty conditions is very important.

Farmers who do their own tune-up work might profit by going to their dealers for a tune-up every few years so their tractor could be tested on a dynamometer both before and after tuning in order to compare its performance to the original rated performance. If the "after tune-up" performance is significantly below its rating, the engine will probably need some major repairs. Knowing this in advance of a critical season would definitely aid the farmer in his planning.

Arthur W. Selders

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STUDENT COMPETENCY SHEET

Module 4: Energy Conservation in Tractor and Farm Engine Operation

Competency 2: Conserve energy through diesel engine tuneup

Introduction:

Tuneup of diesel engines is somewhat simpler than for gasoline engines because there is no spark ignition system or carburetor. Instead, fuel is injected into cylinders where it is ignited by compression. Because diesel fuels tend to be impure and injection parts are precision made, fuel filtration is extremely important in diesel operation. Thus, servicing of fuel filters is a major part of diesel engine tuneup. Loss of power, increased fuel consumption and expensive damage to engine parts can result from improper fuel and air filter servicing.

Resources and Equipment:

Operators or Technical Manuals for each engine serviced

FOS Engines (John Deere)

Mechanics tools, engine test equipment, dynomometer (if available)

Learning Activities:

1. Carefully study your tractor or engine operators or technical manual. Outline tuneup items and procedures.
2. Observe your instructor demonstrate each tuneup procedure. Take notes as he does this.
3. Perform tuneup procedures on your tractor or engine following manufacturer's recommendations. Be sure to:
    a. Clean or replace air filter, check system for leaks.
    b. Clean or replace fuel filters.
    c. Check fuel injection pump timing, adjust if necessary (if testing equipment is available).
    d. Check idle speed, adjust if necessary.
    e. Perform other procedures called for by the operators manual.

NOTE: If you have access to a dynomometer, test engine performance before and after the tuneup.

Evaluation:

You will perform tuneup procedures according to specifications given in the operators or technical manual.

STUDENT COMPETENCY SHEET

Module 4: Energy Conservation in Tractor and Farm Engine Operation

Competency 3: Conserve energy through tractor ballasting

Introduction:

Two identical tractors, side by side, hitched to identical implements adjusted to perform the same work. . . yet, one tractor walks off and leaves the other.

Why? Check closely and you'll probably find that one tractor is ballasted properly while the other is not.

Resources and Equipment:

WVU Extension Circular PM-20.2, Tractor Ballasting to Conserve Fuel

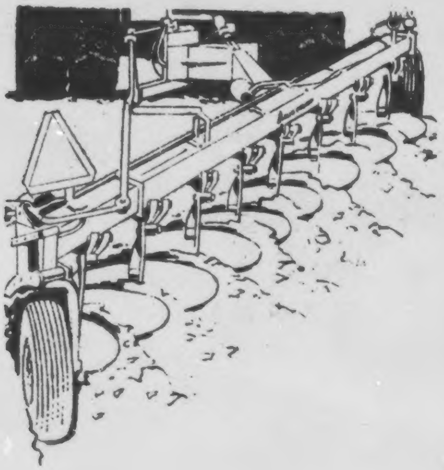
Tire pressure gage, chalk, tractor, plow or disk, mower, rake or baler

Learning Activities:

1. Read WVU Extension Circular PM-20.2, Tractor Ballasting to Conserve Fuel.
    a. Explain the term "ballasting".
    b. Why is proper ballasting important?
    c. How much wheel slippage is normal and desirable?
    d. What are the two methods of ballasting?
    e. What is the purpose of ballast on the front of a tractor?
2. Under the direction of your teacher, complete the following field exercise:
    a. Attach a tillage implement to your tractor--preferably a plow or disk. Following directions given in the above reference, determine slippage while pulling under load.
    b. Observe the tire tread pattern produced while pulling under load.
    c. Now attach and operate an implement that requires little power to pull--a mower, baler or rake. Repeat the exercise, determining slippage and observing tire tread patterns.
    d. Briefly, make ballast recommendations for each of the two field operations.

Evaluation:

1. Turn in answers to questions in Learning Activity #1.
2. Submit a record of your computations, observations and recommendations (Learning Activity #2) to your teacher for grading.



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tractor ballasting to conserve fuel

Agricultural
Engineering

Ballasting a tractor is the process of adding weight to the rear for increased traction and/or to the front for stability and good steering. An improperly ballasted tractor wastes fuel. Inadequate weight on the drive wheels causes excessive slippage, while too much weight increases the amount of horsepower required to drive the tractor through the field.

Rear Ballast

Effective Weight

The effective weight on the driving wheels determines how much a tractor can pull in the lower gears. Depending on the operating surface, the drawbar pull will be from 30-70 percent of the effective weight on the driving wheels. The effective weight is the combination of the tractor's rear tire weight, wheel weights, tire fluid, and weight transferred by hitch mounted implements.

Wheel Slippage

Since there is little control over the operating surface, slippage of the drive wheels must be controlled by adding weight. Tractors are designed to give maximum performance with about 15 percent rear wheel slippage. Slippage greater than 15 percent causes excessive tire wear and reduces tractor productivity. If wheel slippage is less than 15 percent, the tractor is possibly carrying too much ballast, placing extra stress on both the tires and the power train.

Tire Pressure

Before making adjustments for wheel slippage, check the rear tire pressure. Use a low pressure gauge and take the reading with the valve stem at the bottom of the rim. If calcium chloride is used in the tire, wash the gauge after using to avoid corrosion.

Measuring Slippage

To measure the amount of wheel slippage, complete the following steps:

1. Mark a reference line on the side of the drive wheel tire with chalk.
2. Drive the unloaded tractor for 10 complete revolutions and mark the distance traveled.
3. Drive the tractor while under full implement load and mark the distance traveled during 10 complete revolutions.
4. Determine the percent slip from the formula:

$$\%\ \text{slip} = \left(1 - \frac{\text{distance traveled loaded}}{\text{distance traveled unloaded}}\right)100$$

Example: A tractor advances 96 feet with a load and 120 feet without a load. What is the percent slip?

$$\%\ \text{slip} = \left(1 - \frac{96}{120}\right)100$$

$$= \left(1 - .8\right)100 = .2 \times 100 = 20\%$$

For most efficient operation, 20 percent is too much slippage.

Tire Traction Check

An approximate method for checking proper ballast is to observe the tire tread pattern produced when pulling under load, using the following guidelines:

Too little.—When the weight on the tires is too little, the tread marks are wiped out entirely due to excessive slippage, which reduces forward progress.

Too much.—When too much weight is used, the tire tracks will be sharp and distinct in the soil.

Proper weight.—When the tires are weighted properly, a small amount of slippage occurs. The soil between the cleats in the tire pattern is shifted, but the tread pattern is still visible. (Figure 1.)

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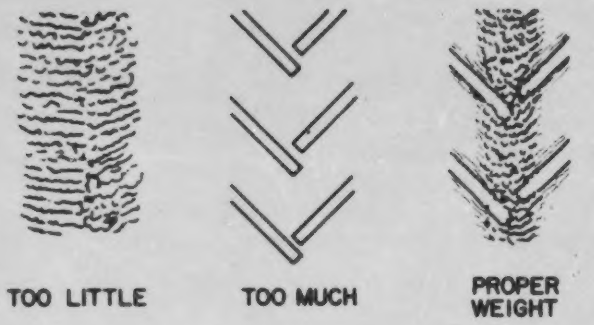

Figure 1. Tire Traction Patterns

Considerations

Avoid both too little or too much ballast. Too little ballast causes excessive slippage. Too much ballast increases the horsepower needed to move the tractor through the field and reduces the power available for pulling an implement. It also increases soil compaction which may retard crop growth.

Ideally, a tractor should be ballasted properly for any of the high draft operations in crop production, such as land preparation. The ballast should then be removed for the low draft operations. This ideal situation often cannot be practically achieved because one of the cheapest and easiest means of increasing ballast is to use liquid in the tires. Because of the special equipment needed for adding liquid ballast to tractor tires, it is usually regarded as a permanent part of the tractor. Cast-iron weights are the variable portion of the total ballast since they can be installed and removed with relative ease.

Dual Rear Tires

As engine horsepower of farm tractors increases, traction problems increase. Compaction of soil is also a major problem with bigger tractors. Dual rear tires are one way to add more weight for traction while reducing the compaction by spreading the weight over a larger area.

There are no universal guidelines for using or not using dual wheels. Each situation must be examined to determine the feasibility of dual tires. Consult your tractor dealer prior to installing duals to make sure the power train components can withstand the extra stress of dual tires.

Advantages

- Dual tires with added ballast give more ground contact. This reduces slippage, increases ground speed, improves work rates, and possibly reduces fuel consumption.
- Tractor stability is improved by the greater ground contact and tread width.
- Operator fatigue is lessened because the ride is smoother.
- Duals increase floatation when replacing single tires of the same size.
- Dual wheel tractors have a higher potential for all-season use.

Disadvantages

- Some tractor axles, bearings, and power trains may be overstressed by dual wheels, with resulting damage to the tractor.
- Other than reducing soil compaction, there is no economic gain in dual tires over single tires of the same size if the drawbar load is relatively light.
- Dual tires may make the tractor more difficult to turn and if short turns are made, the stress on the tread lugs may cause the lugs to tear.

Front Ballast

The requirements for front ballast vary widely between operations. Adequate ballast for stability during transport is important. However, weight added to the front for transport may not be needed for field operation. For example, a tractor with an 8-unit planter mounted on an integral tool bar needs front ballast for safe transport. But little front ballast is needed for stability when this implement is used in the field. The opposite is true of a semimounted plow. Little front ballast is needed for transport, while weight is needed during field operation to keep the front of the tractor in firm contact with the soil.

The amount of front ballast needed for transport may be difficult to determine, even with experience. The front wheels may appear to be in firm contact with the ground, but at higher transport speeds more weight may be needed on the front tires to steer the tractor. When uncertain as to how much ballast to use, it is usually best to add a little extra than not enough.

When determining the amount of field ballast required, the general rule of thumb is:

1. For mounted implements, ⅓ of the total tractor weight on the front and ⅔ on the rear.
2. For towed implements, ¼ of the total tractor weight on the front and ¾ on the rear.

These rules are considered a good starting point from which ballast can be added or removed as needed under field conditions.

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STUDENT COMPETENCY SHEET

Module 4: Energy Conservation in Tractor and Farm Engine Operation

Competency 4: Conserve fuel in tractor and machinery field operation

Introduction:

Each time you operate a tractor, you are constantly making decisions. "How fast shall I go?" "How deep shall I set the plow?" "Shall I turn off the engine or let it idle while I replace that bolt?" And many more. The decisions you make have a marked influence on fuel consumption which, in turn, influences the condition of your bank account.

Resources and Equipment:

WVU Extension Circular PM-18.3, Tractor Operation for Fuel Savings

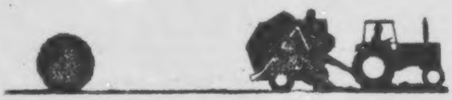
Slide set, "Fuel and Farm Machinery," available from WVU Agricultural Engineering Extension, and slide projector.

Learning Activities:

1. View the slide set, "Fuel and Farm Machinery." Some parts of the slide set may review topics you have previously covered. Pay particular attention to those items dealing with field operation of tractors and machinery. Take notes.
2. Read WVU Extension Circular PM-18.3, Tractor Operation for Fuel Savings. Record fuel-saving techniques in your notes.

Evaluation:

On a written examination, be able to list and discuss at least five fuel-saving techniques you can use in tractor and machine field operations.



PM - 18.3

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tractor operation for fuel savings

Agricultural Engineering

The amount of tractor fuel required to perform a specific amount of work depends largely upon how the tractor is operated. The load, engine speed, gear used, amount of turning and amount of engine idle time can cause fuel consumption to vary considerably.

SHIFT UP—THROTTLE BACK

Ideally, a farmer should use an implement that will load the tractor engine to its rated capacity. Under these conditions, fuel efficiency will be close to maximum and the work will get done quickly.

Many jobs done by farm tractors do not require full rated capacity. In fact, studies indicate that on the average, a farm tractor is loaded to only 50 percent of its rated capacity. When performing light drawbar work, reducing the engine speed will improve fuel efficiency.

Reduced engine speed for light drawbar work will improve fuel efficiency.

This fact is proved conclusively by a test conducted during the Tractor Test Program at the University of Nebraska. A tractor is tested in the following manner.

1. The tractor is tested for maximum drawbar horsepower in a gear selected by the tractor manufacturer.

2. In the same gear, the tractor is tested pulling 50 percent of the maximum power run load.

3. The tractor is tested in a higher gear and at a reduced engine speed to maintain the same pull and travel speed as in run 2.

Results: During run 3, diesel tractors use about 75-80 percent as much fuel as during run 2, even though they are both performing the same amount of work. Gasoline engines also operate more efficiently during the lower speed run; however, the reduction is not as great.

Many diesel engines run more efficiently at 50 percent load and a reduced engine speed than at the 100 percent load and full engine speed. Because of this trait, a farmer can often use a large diesel tractor at reduced engine speeds for light drawbar loads and actually use less fuel than he would use with a smaller tractor working at its rated capacity.

A large diesel at reduced engine speeds for light drawbar loads may use less fuel than a smaller tractor working at rated capacity.

Figure 1 is from test data for a 50 horsepower diesel

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tractor. Note that the fuel efficiency increases as the horsepower output increases up to about 80 percent of the maximum horsepower produced at that engine speed. Further increase of power output causes the fuel efficiency to decrease. At partial load, the fuel efficiency improves as the engine speed is reduced. For the tractor tested, the best fuel efficiency was obtained at about 30 horsepower and 1400 rpm.

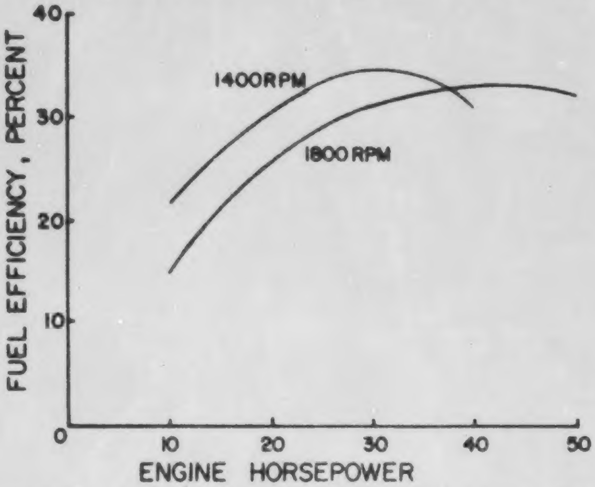

Figure 1. The Effect of Engine RPM and Output upon the Fuel Efficiency of a Diesel Tractor.

For maximum fuel efficiency, select the gear which provides the desired speed of forward travel at the reduced engine speed. On tractors having a wide range of gears, it is possible to have engine speeds which give nearly optimum fuel efficiency at the desired travel speed.

PTO WORK REQUIRES MATCHING

It is especially important to match tractors to the load when performing PTO work because PTO driven equipment usually must be operated at the rated engine rpm to perform properly. Although shifting up and throttling back will help achieve maximum fuel economy with light drawbar work, PTO operations at partial load do not offer this opportunity.

Shifting up and throttling back helps conserve fuel when doing drawbar work.

SHUTTING OFF THE ENGINE

An Illinois study showed that, on the average, tractors idle for more than 12 percent of their total hours of operation. An idling engine may use more than ½ gallon of fuel per hour. Rather than letting the engine idle for long periods of time, shut off the engine to help conserve fuel.

SUMMARY

- Operate the tractor at the rated load (rated engine rpm at full hand throttle) at all times.
- Combine machines to load the tractor to its rated capacity.
- When pulling light loads, shift up and throttle back.
- Don't idle the engine excessively.

For further information, contact your County Extension Office.

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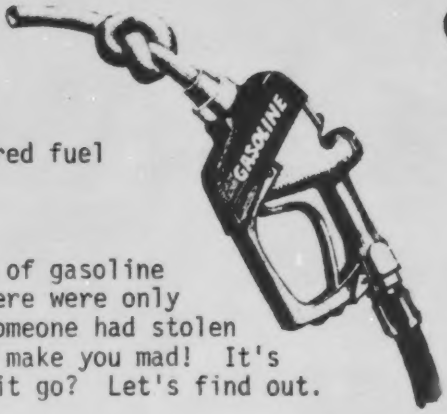
Agricultural Engineering

STUDENT COMPETENCY SHEET



Module 4: Energy Conservation in Tractor and Farm Engine Operation

Competency 5: Protect quality and avoid losses in stored fuel

Introduction:

Let's say you bought and paid for 100 gallons of gasoline for your tractor. But as you used it, you found there were only 85 gallons in the barrel. You might suspect that someone had stolen 15 gallons. A mighty expensive loss, and enough to make you mad! It's doubtful if anybody stole your fuel, but where did it go? Let's find out.

Resources and Equipment:

NRAES Circular FS-17, Reducing Gasoline Storage Losses

FOS Fuels, Lubricants and Coolants (John Deere), or

Fuels and Lubricants, AAVIM

Learning Activities:

1. Read NRAES Circular FS-17, Reducing Gasoline Storage Losses, and pp. 19-28, Fuels and Lubricants or pp. 16-25 FOS Fuels, Lubricants and Coolants. Answer the following questions:
    a. In what ways can evaporation losses of stored gasoline be reduced?
    b. At today's gasoline prices, how long would it take to pay for a simple shade and a pressure-vacuum relief valve for a 300 gallon tank? (You may have to call a local supplier for prices.)
    c. How can gum deposits in gasoline be avoided?
    d. How does water get in fuel tanks? How can it be prevented?
    e. How can quality of stored diesel fuel be maintained?
2. On a field trip, observe fuel storage systems on your farm or on farms in your community. For each system observed, outline steps which would help to eliminate losses and maintain quality of fuel stored.

Evaluation:

1. Turn in your answers to questions in Learning Activity #1.
2. Turn in your suggestions for eliminating losses and maintaining quality of fuel in storage systems observed in Learning Activity #2.

Agricultural
Energy
Management

Reducing Gasoline Storage Losses

As energy costs cut deeper into farm profits, farmers are seeking ways to reduce fuel consumption whenever and wherever possible. There are several ways to reduce the amount of fuel wasted in your operation. One of them is the manner in which fuel is stored, easily overlooked but fairly simple to correct. Fuel-tank color, location, type of filler cap, plus fuel leaks and fuel quality all influence fuel losses. Losses from one gasoline storage tank may be costing you as much as $75 per year.

Typical Gasoline Losses from a 300 gallon Tank

Tank Configuration	Gasoline Losses, Gallons per Month
Red Tank in sun	9 - 10
White Tank in sun	6
Red Tank in sun with pressure-vacuum relief valve	3.2
Tank in shade	2.4
Tank in shade with pressure-vacuum relief valve	1.3
Underground Tank	less than 1

Based on information from Missouri and Nebraska. Evaporation loss may be slightly less in the Northeast United States due to less solar radiation received.

Tank Color

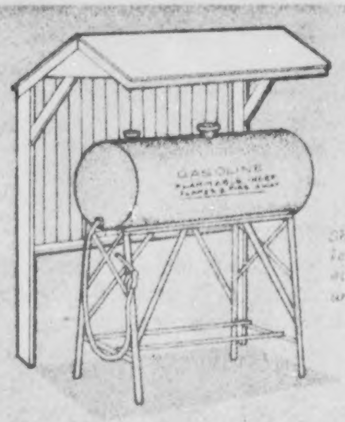
Fuel tanks painted a dark color are subject to high evaporation losses. If your storage tank is rusty or dull red, you can cut evaporation losses one-third by painting the tank with white or aluminum paint. For example, a red fuel storage tank exposed to direct sunlight will lose approximately 10 gallons per month through evaporation, whereas a white tank in the same location will lose about 6 gallons per month. You can expect to recover the cost of the paint in approximately one year, through gallons of gasoline saved.

It is a common misconception that the law requires all fuel storage tanks to be painted red. Most states in the Northeast have no restrictions on tank color, except for small portable containers. Check on local regulations with your fuel supplier or local fire marshall.

Tank Location

Shade makes a substantial difference in the amount of fuel that evaporates from a fuel storage tank. Shaded tanks lose 75 percent less fuel than tanks exposed to sunlight. Intense sun in summer and the lighter grade fuels required for easier engine starts in winter make evaporation losses a year-round problem.

Tank shading can be provided by a large tree, but in most instances a tree will not provide sufficient shade during winter months. An open-front shed constructed over fuel tanks is the most effective means to provide shade. The front of the shed should face away from the sun, and openings should be provided below the roof to prevent heated air from being trapped over the tanks. If properly shaded, tank color has little effect on fuel loss. Buried gasoline tanks, of course, have almost no evaporation losses.

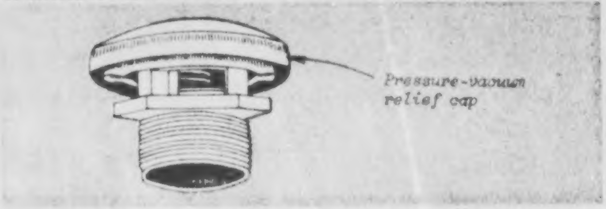


Shaded tanks lose 75% less fuel through evaporation than unshaded tanks.

Filler Caps

You should look critically at the filler cap on your fuel tank. A **pressure-vacuum relief cap** will cut evaporation losses in half. This small item may reduce evaporation losses by 40 to 50 gallons per year for a red, unshaded storage tank.

Pressure-vacuum relief caps are designed to open at 2 to 3 psi of pressure or 1/16 psi of vacuum. It is a good practice to closely watch the tank for a few days following installation of such a cap because pressure buildup may cause new leaks to occur. The nozzle on a gravity-flow tank may be the source of particularly troublesome leaks. A shut-off valve at the tank should eliminate these leaks.



Pressure-vacuum relief caps will not work on fuel pumps designed with an air bleed. Check with the pump supplier to see if it will hold the pressure created by the cap.

Fuel Leaks

If a fuel storage system leaks a drop of gasoline every 2 minutes, approximately 35 gallons per year are being lost. That's enough fuel to plant 50 acres of corn!

Examine all connections between the tank outlet and the hose nozzle, as well as the hose itself. Are any of the connections moist or caked with dust? Does the ground indicate fuel leakage from the hose or tank? If so, both fuel and money are being wasted.

Fuel leakage can often be corrected by simply tightening connections. In more stubborn cases, it may be necessary to disassemble the system and apply a thread sealant during reassembly. Replace cracked or damaged fittings or hoses, and be sure that the fuel filler is clean and sealing properly.

Fuel Quality

Losses are only one aspect to consider when trying to reduce gasoline evaporation. Nearly as important is the reduction in gasoline quality that occurs with evaporation. Fuel composition varies depending on the season of the year.

Winter-grade gasoline vaporizes more readily than summer-grade. Although the lighter, winter-grade fuel aids in easier starts and more rapid warm-ups during cold weather, the more volatile or lighter components of winter-grade fuel are more easily evaporated during storage. Under certain storage conditions, fuel delivered as a winter-grade gasoline will, through evaporation of the lighter components, change to the equivalent of a summer-grade gasoline.

As this deterioration occurs, the percent of gum content increases in the gasoline. When such gasoline is used, an engine starts harder and requires more choking. Also, the gum is deposited in the carburetor, in the intake manifold, on the valves, and lacquer deposits form on the pistons and cylinder walls. All of these factors cause unfavorable engine operations, excessive engine wear, and excessive fuel consumption.

Recommendations

The following steps are recommended:

1. Paint fuel tanks white.
2. Provide suitable shade for fuel tanks.
3. Install pressure-vacuum relief filler caps.

Above all, take all necessary safety precautions when using, storing, or handling gasoline.

- Locate tanks at least 50 feet from buildings, preferably both downwind and downhill from the buildings.
- Provide a sturdy tank-support stand.
- Label each tank in large letters as to contents, e.g.: GASOLINE, DIESEL.
- Label each tank: FLAMMABLE—KEEP FIRE AND FLAME AWAY
- Keep the area around the tank free of weeds, high grass, debris, rubbish and litter.
- Shut off engines when refueling.
- Do not smoke or light matches around fuel.
- Keep a dry chemical extinguisher handy at all times.

This publication was adapted by R.K. Koelsch, Extension Agricultural Energy Specialist at Cornell University from a University of Nebraska publication prepared by David Shelton and Leonard Bashford.

NRAES

FS-17

The Northeast Regional Agricultural Engineering Service is an activity of the Cooperative Extension Services of the Northeast Land Grant Universities and the United States Department of Agriculture.

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STUDENT COMPETENCY SHEET

Module 5: Energy Conservation in Farm Truck and Pickup Usage

Competency: Conserve fuel used in vehicle operation

Resources and Equipment:

Index cards; mechanic's tools and test equipment;
tire pressure gage; vehicle owner's guides

Learning Activities:

1. Fuel records. Keeping vehicle fuel records can save fuel and money. They provide a continuous reminder that fuel economy depends on driving habits. Further, if miles per gallon show a sudden decrease, they alert the operator to vehicle problems such as fouled spark plugs or clogged air filters.
   - a. Reproduce copies of the Vehicle Fuel Use Record on index cards.
   - b. Keep in the glove compartment or on the dash of your pickup and/or truck.
   - c. Start the record by entering odometer mileage next time the fuel tank is filled.
   - d. Then record mileage and gallons each time the fuel tank is filled.
   - e. Determine miles per gallon (MPG) for each tank-full. To find MPG, divide miles travelled between fillups by gallons of fuel required to refill the tank.
   - f. Try to improve MPG between fillups. This calls for a conscious effort to change driving habits. Improvement may also result from maintenance procedures.
   - g. After a period of six to eight weeks, compare record results with your classmates. Determine percentage MPG improvement, if any.

VEHICLE FUEL USE RECORD

Date	Mileage	Miles Driven	Gallons Fuel	MPG
		------	------	------

2. Vehicle maintenance. Assuming the engine is not worn out, there are eight major fuel robbers to check if you're serious about reducing fuel consumption. Following specifications given in your owner's guide, check and adjust or replace the following in your farm truck or pickup. Ask your teacher for assistance, if needed.

    a. Spark plugs
    b. Points/condensor (most newer models have electronic ignition systems)
    c. Ignition timing
    d. Air filter
    e. PCV system
    f. Idle mixture and speed
    g. Motor oil (multigrade oils reduce fuel consumption)
    h. Tire pressure

3. Driving habits. The way a person drives affects fuel economy. From your own observations and from any references available (you may want to see your school's driver education teacher), list at least ten driving habits that adversely affect miles per gallon of fuel.

    a. Judge yourself (guilty or not guilty) on each of the ten or more habits identified.

    b. Print the ten bad habits on the back of an index card. Tape it to the dash of your pickup or truck as a reminder to avoid those habits.

4. Vehicle selection. In selecting and purchasing a vehicle, the buyer must make a number of decisions. Cost, comfort, convenience, safety and fuel economy must be carefully weighed.

    a. Visit one or more auto dealer showrooms or lots. Examine at least three different pickup models. Using information on the window stickers, record for each model the following:

Model			
List price			
Weight			
Engine size & type			
Transmission type			
Accessories (power)			
Mileage ratings			

b. Prepare a brief written report. Analyze the effect of various options on mileage ratings.

Evaluation:

1. You will check and adjust, on your farm truck or pickup, the eight items listed in Learning Activity #2. This maintenance will be performed according to manufacturer's specifications.
2. Turn in your list of driving habits, your self-rating and your reminder list assembled in Learning Activity #3.
3. Turn in, for instructor grading, your vehicle information and written report for Learning Activity #4.

STUDENT COMPETENCY SHEET

Module 6: Energy Conservation in Crops Production

Competency 1: Conserve energy in tillage operations

Resources and Equipment:

University of Delaware Bulletin No. 120, NO-TILLage

No-Tillage Farming (Ortho, Chevron Chemical Company)

Pennsylvania Farmer, "The More and Less of No-Till Corn," March 8, 1980, and "He No-Tills Alfalfa into Corn," May 9, 1981

Sharp and dull pocket knives, wood block

Learning Activities:

1. Given a sharp pocket knife, a dull one, and a block of wood, whittle with the two knives. Compare effort required by each knife to draw the blade through the wood. Describe how the principles observed would apply to tillage implements such as plows, chisels and cultivators. Your conclusions?

2. Since introduction of effective herbicides a few years ago, minimum tillage and no-tillage crop production systems have become popular. Chemical controls can eliminate need for plowing, disking, harrowing and cultivation operations. Fuel and labor savings far exceed cost and energy expended in producing, purchasing and applying chemicals needed for weed and insect control.

   Through study of NO-TILLage, No-Tillage Farming, articles in Pennsylvania Farmer and other publications, answer the following questions:

   a. What are eight advantages of no-tillage farming?

   b. What are four disadvantages?

   c. How can a legume cover crop reduce energy consumption. What legumes may be used in your community?

   d. What other crops are suitable as cover crops?

   e. What crops can be produced by no-tillage methods?

   f. What equipment is needed to produce crops by the no-tillage method? (Consider requirements for planting, fertilizing, weed control, insect control)

g. What chemicals are used to control weeds and grasses in no-tillage farming? When should they be applied?

h. How can seed, plant and leaf attacking insects be controlled?

3. Invite a farmer who has grown crops by no-tillage methods to visit with your class. Question him with regard to all phases of no-tillage operations.

Evaluation:

1. Turn in your answers to questions in Learning Activity #1.

2. Using any available resources and references, outline a plan for producing a crop by no-tillage methods on your farm or one in your community. Turn in your plan for grading.

Be sure to include

...approximate dates of each operation
...recommended varieties and seed rates
...types of chemicals and application rates
...fertilizer applications, analyses, and rates
...other information deemed essential for success

Conserves Energy
Builds Soil Fertility
Increases Profits

NO-TILLAGE

COOPERATIVE EXTENSION SERVICE UNIVERSITY OF DELAWARE BULLETIN NO. 120

W. H. MITCHELL
EXTENSION AGRONOMIST

What is No-Tillage?

No-tillage is a convenient term to identify a general type of crop production system. It takes many forms, and may also be called reduced-tillage, minimum tillage, 0-till, or conservation tillage. All of these systems have one thing in common, however. They are planted with minimal soil disturbance into some type of plant residue. It could be corn stalks, sod, soybeans, or small grain stubble.

What Can No-Tillage Do For You?

No-tillage can save energy, or make it possible to use energy more efficiently, and has the potential to increase yields. Results of field experiments have shown that it will also increase organic matter, conserve moisture and raise the nutrient-holding capacity of soils. Fourteen pairs of farm fields (tillage vs. no-tillage) involving one to eight years of continuous corn production, were selected for a broad range of chemical and physical soil measurements. These tests confirmed that no-tillage is a soil builder. The test results are worthy of comment in view of how soil modification, through no-tillage, can affect production practices.

The purpose of this bulletin is to review information generated by Delaware Agricultural Experiment Station research and show what no-tillage can accomplish in the important areas of energy and soil conservation. These, of course, influence profits in corn production.

No-Tillage Saves Energy

Shifting to no-tillage has a dramatic effect on energy consumption. Comparisons among tillage

No-tillage goes well with irrigated corn, especially where energy efficient low pressure systems are used.

No-Tillage Information In This Publication:

Comparison of energy use in corn production systems - **p.2**
How no-till works in the cornfield - **p.3**
Conservation of nutrients - **p.3**
Nitrogen tie-up by humus - **p.4**
Conservation of soil moisture - **p.5**
Additional nitrogen needs - **p.5**
No-till summary - **p.6**

systems can be made using principal inputs for corn production shown in Table 1.

Nitrogen is an Energy Guzzler

About 70 percent of the total energy involved in the principal production inputs shown in Table 1 is tied up in 100 pounds of nitrogen fertilizer. In a more complete list of production inputs, including irrigation, grain drying, and transportation, nitrogen would still be the number one energy factor, making up about 32 percent of the total. Options for winter annual cover crops include crimson clover, red clover, field peas and hairy vetch. Vetch is most attractive in that it will supply a minimum of 100 pounds of nitrogen (22.1 gallons gasoline equivalent) at an energy cost of 2.5 gallons of gasoline. Even with 20 pounds of nitrogen added as row fertilizer, the total energy requirement would be only 40 percent of that required for conventional tillage.

Legume Cover Crop Cuts Energy Needs

A legume crop such as crimson clover, soybeans or hairy vetch will

BEST MILEAGE WITH NO-TILLAGE USING A COVER CROP

	Energy for 1 A corn (Gallons gas equiv.)
Tillage With Moldboard Plow	**33.7**
Tillage With Chisel Plow	**32.0**
No-Tillage With Cover Crop or Rotation	**12.9**

TABLE 1. ENERGY FOR CORN PRODUCTION IN GASOLINE EQUIVALENTS

	Conventional Tillage		
	Moldboard Plow	Chisel Plow	No-Tillage With Cover Crop or Rotation
Production Input	gallons gasoline per acre		
Plant	1.0	1.0	1.0
Cultivation			
Moldboard Plow	3.0	---	---
Chisel	---	1.9	---
Disc	1.0	1.0	---
Springtooth	0.6	---	---
Cultivate (1)	1.5	1.5	---
Fertilizer			
Nitrogen	22.1	22.1	4.4
Phosphorus	0.6	0.6	0.6
Potassium	1.8	1.8	1.8
Chemicals			
Atrazine	0.4	0.4	0.4
Simazine	0.4	0.4	0.4
2, 4-D	---	---	0.1
Toxaphene	0.9	0.9	0.9
Furadan	0.4	0.4	0.4
Paraquat + X-77	---	---	0.4
Cover Crop	---	---	2.5
Total	33.7	32.0	12.9

SUBSTITUTE HERBICIDES FOR TILLAGE; IT'S A GOOD ENERGY TRADE-OFF

Tillage	6.1 Gallons Gas Equivalent
Herbicides	0.5 Gallons Gas Equivalent

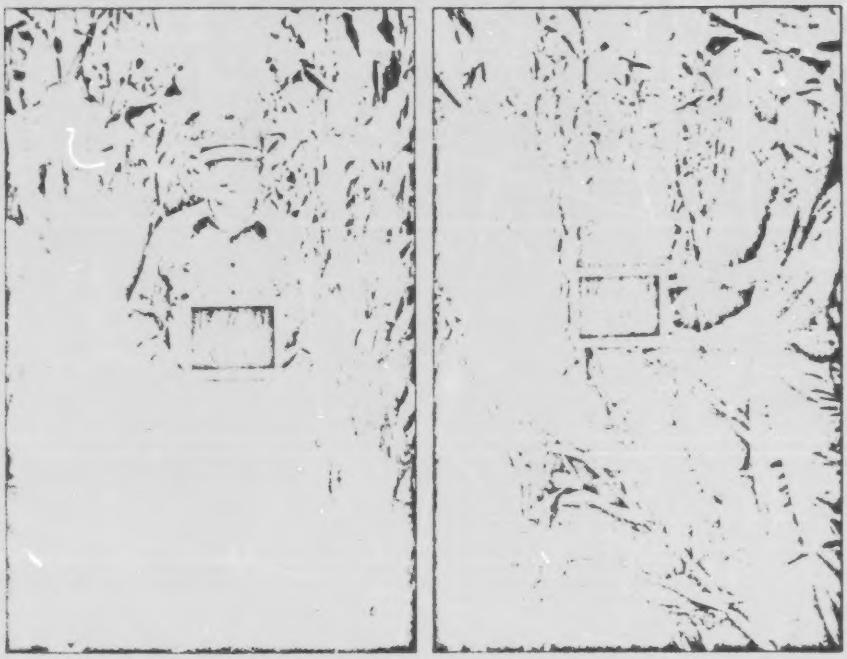
provide enough nitrogen for at least the first 100 bushels of corn. In a three-year test on loamy sand soil, vetch alone supplied the nitrogen needed for 120 bushels of corn. Additional nitrogen, broadcast as ammonium nitrate, didn't increase yields but it ran up the energy bill. When viewed on an energy input-output basis using gasoline as an energy gauge, each gallon put into conventional tillage returned 7.7 gallons as grain. Switching to no-tillage with vetch increased the return to 22.6 gallons per gallon invested. This represents nearly a 300 percent increase in energy efficiency. A few years ago, it was "only energy." Today energy is a big part of the bottom line.

Organic Matter Increased by No-Tillage

A build-up of organic matter or humus under no-tillage was clearly evident in the test fields. It was most apparent in soil depths up to three inches, but in some cases reached depths of nine inches. Increases in humus ranged from zero for some reduced tillage fields (chisel plowed) to almost 50 percent for fields in no-tillage for seven to eight years. This build-up in organic matter explains the higher yield potential of no-tillage fields.

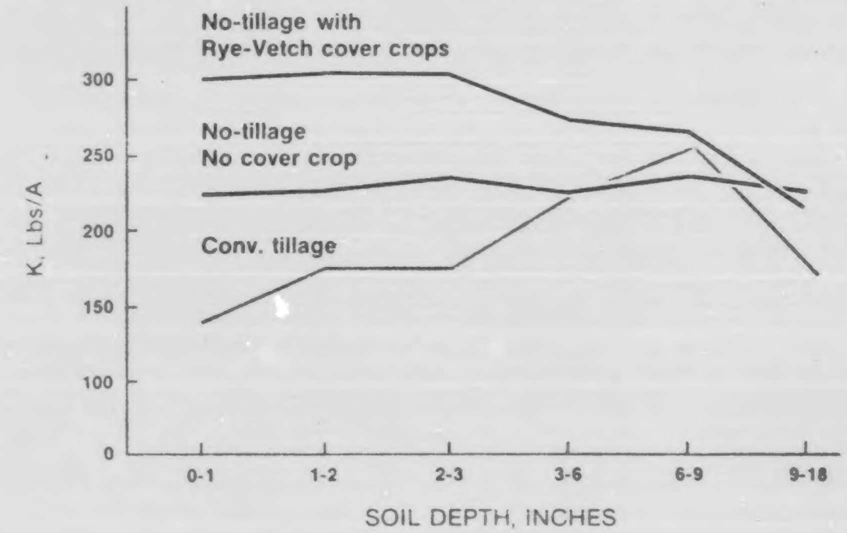
Nutrient Exchange Capacity Higher With No-Tillage, But Leaching is Reduced

A principal contribution of organic matter is the added



Research results and farmer experience confirm that corn lodges less under no-tillage.

FIGURE 1. NO-TILLAGE CUTS K LEACHING AND COVER CROPS ACT AS K PUMP, ADDING UP TO NUTRIENT CONSERVATION.



NO-TILLAGE - VETCH SYSTEM WORKS IN THE CORNFIELD

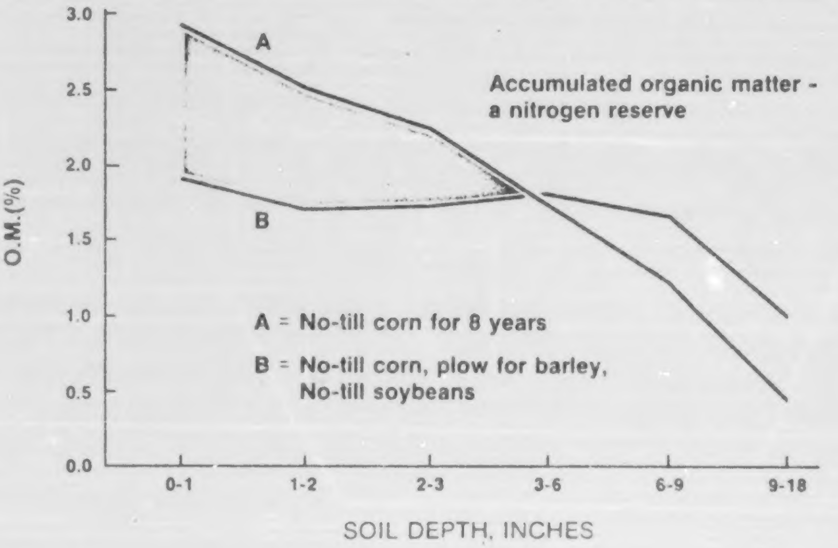
No-Tillage Cover Crop	Broadcast Nitrogen, Lbs/A 0	50	100
	Bushels/A		
None	58	94	101
Sp. Oats	73	108	121
Sp. Oats + Vetch	120	116	116

TABLE 2. N TIE-UP BY HUMUS IN 7 YEARS OF NO-TILLAGE.

	Conventional Tillage	No-tillage		
		Rye Cover	Vetch Cover	Corn Residue Cover
Lbs. of soil in 0 to 3 inch depth	1 Million	1 Million	1 Million	1 Million
% organic matter	1.47	1.93	2.13	1.83
Lbs. organic matter/A	14,700	19,300	21,300	18,300
Lbs. total N/A from organic matter (5%N)	735	965	1,065	915
Lbs. N tied-up by no-tillage system	-----	230	330	180

nutrient-holding capacity it gives to soil, called the cation exchange capacity. It minimizes the leaching of such nutrients as calcium, magnesium and potassium from a field. Soil in the average no-tillage field had 21 percent more exchange capacity than soil in tilled fields. Some long-term no-tillage fields had 55 percent more exchange capacity. This highly desirable change in soil activity generally extended to a depth of six inches, in contrast to organic matter accumulation which was concentrated in the top three inches of soil.

FIGURE 2. ORGANIC MATTER - STORE IT OR USE IT



Potassium Accumulates Under No-Tillage

Soil samples from no-tillage fields contained 30 percent more potassium than soil from tilled fields. There was evidence that accumulated organic matter under no-tillage effectively reduced potassium leaching. In a specific comparison where 200 pounds of potash had been broadcast annually since 1972, there was 60 percent more potassium in the three-inch soil depth under no-tillage. In the tilled field, potassium levels increased steadily from 134 to 254 pounds per acre as sampling depths increased from the soil surface down to nine inches. Under no-tillage, potassium levels never dropped below 260 pounds per acre. Since this loamy sand soil was plowed each year, the dramatic rate of leaching is an indication of what can happen to potassium in a single season under irrigation and heavy rainfall. Under the same conditions without tillage, there was no evidence of potassium leaching.

No-Tillage Cover Crops Act as a Nutrient Pump

In test fields no-tillage cover crops served as nutrient pumps, lifting phosphorus, potassium, boron, manganese and zinc from deep in the soil and concentrating them in the top soil layers. For example, potassium in the top nine inches of soil under full tillage tested at 189 pounds. No-tillage without a cover crop raised the K level to 231 pounds, thanks to accumulated organic matter and reduced leaching. When rye and vetch cover crops were added to the no-tillage program, K accumulated to a high level of 292 pounds. Similar nutrient accumulation in topsoil occurred with other elements, but was most striking with boron. Boron levels under no-tillage without a cover crop were similar to those observed under

SAVE SOIL MOISTURE WITH NO-TILLAGE

Tillage Practice	Percent Soil Moisture[1]
Tillage (Plow, Disc, Cultivate)	6.6
No-Tillage; Corn Residue Cover	9.0
No-Tillage; Rye or Vetch Cover Crop	12.2

1) Soil Surface to 3-inch depth

Legume covers are non-reflective and good collectors of solar energy which adds to their value as no-tillage mulches.

full tillage; however, when rye or vetch covers were included, significant amounts of soil boron appeared in the topsoil. This was clear evidence that the cover crop nutrient pump was working, an important contribution with a highly leachable nutrient like boron.

How Much Nitrogen is Needed for No-Tillage?

Field tests showed that soil organic matter accumulates under a no-tillage system of corn production. Assuming that organic matter contains about five percent nitrogen, it's clear that a large amount of nitrogen can be immobilized by no-tillage systems. Immobilized nitrogen is unavailable to corn plants on a short-term basis. It becomes part of the nitrogen reserve but, more importantly, is a key component of organic matter which would never form without nitrogen. On the other hand, nitrogen alone will not cause an accumulation of organic matter. It occurs because of a reduction in tillage.

As organic matter accumulates, less nitrogen is available for corn plants. As a result, yields are often reduced or, at best, no-tillage does not reach its full potential. Even under no-tillage, organic matter will not increase above a certain level. Until this level is reached, there will be a net reduction in the amount of nitrogen available to the corn crop. Additional nitrogen must be added to cover the deficit. The specific amount will depend on liming practices, soil moisture, and the extent to which tillage is reduced. An additional 30 to 50 pounds of nitrogen usually meets short-term needs.

Accumulation of organic matter and residual nitrogen is well illustrated on farm fields A and B as shown in Fig. 2. In each case the farmer was pleased with his tillage system. On both fields the organic matter level was higher than in nearby tilled fields, but with alternate-year tillage on field B there was less organic matter accumulation. There was also no evidence of a nitrogen deficiency, which reflects the faster recycling of organic nitrogen. This could also be explained by nitrogen contribution of soybeans in the rotation.

Field A has produced outstanding corn yields but the farmer regularly uses more nitrogen than would be applied on tilled fields. Occasional tillage with a chisel plow, disc or other implement will aerate the soil and release some nitrogen. There is much speculation about the wisdom of doing this every three or four years, but there is no good evidence to show that it is necessary to use a moldboard plow to achieve consistently high yields. In field A, the factors associated with high organic matter, such as higher exchange capacity, potassium accumulation, micro-nutrient recycling, and soil moisture conservation, have contributed to increased yields. In order to achieve these benefits, at least until more is known about the nitrogen recycling pattern at higher levels of organic matter, additional nitrogen should be applied. If a nitrogen fixing legume such as hairy vetch or crimson clover could be used as a winter annual in the crop rotation, additional fertilizer nitrogen would not be needed and the no-tillage system would be even more energy efficient and productive.

In Summary, No-Tillage:

- Builds Soil
- Reduces Fuel Consumption
- Reduces Leaching - Conserves Nutrients
- Saves Water
- Stops Soil Erosion by Wind and Water
- Increases Yield Potential

No-Tillage Will Improve Soil, But in Return You Must:

- Change Planting Equipment
- Improve Management Skills
- Substitute Paraquat for Tillage
- Add N to Compensate for N Tie-up in Organic Matter
- Have Conviction in Your Belief in No-Till

The author gratefully acknowledges the assistance of W. D. Gravelle, student, Plant Science Department, with data collection.

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The more and less of no-till corn

More Dollars
less time,
more soil saved,
less fuel
more acre
less equipment
says dairyman

by SUZANNE HALAS

Like most farmers, John Koons, Franklin County, Pa., doesn't like to toot his own horn. He credits his 135 bushels per acre to no-till. He figures others can duplicate this by following the same principles.

The farmer started no-tilling in 1970 after keeping a close eye on how it worked out for a neighbor. He could count plenty of advantages then. Today he can count a few more.

Top on the list is erosion control, especially important in hilly Pennsylvania. "Erosion is minimal. No soil washing off your farm creating gullies and taking away your top soil. The water you do see running off is clean."

Some say top soil is the biggest asset a farm has. Koons, a 120 head dairy farmer says, "I always had a feeling since I was a boy that a farm should be in better shape when I'm done with it than when I started. I can't feel that way if it all washes away."

Going hand in hand with the erosion prevention is the extra moisture saved with no till. According to Koons, mulch and stalks left standing in the winter act as a small snow fence, keeping the snow and top soil from blowing away. "The man with a bare field over winter will pretty often see soil blow away." In dry weather, mulch will help retain moisture, cutting down on evaporation.

No-till also saves fuel because planting is done with one sweep across the field says Koons. This eliminates plowing, disking, harrowing and hauling rocks, a problem in southern Pennsylvania.

For the same reason, less equipment is needed.

Much labor and time also are saved. Time is important . . . more emphasis can be placed on managing cows or other farm jobs, he says. Also, corn can be planted quickly, on time.

The extra time means you can handle more acres for a bigger profit. Every year Koons has somebody new ask him to plant for him,

John Koons stands in a ditch created by erosion when this field was planted conventionally. Today the ground is protected by corn stubble, cutting down on erosion and moisture loss.

and now along with 150 acres of his own land, he's renting 275 acres and contract no-tilling 400 acres for neighbors. "It's easier for me to no-till 800 acres of corn today than to plant 60 conventional acres," says Koons.

One elderly couple didn't farm their land because they were losing so much soil. After seeing his no-till fields, they asked Koons to plant for them. Now they're making a profit, and are happy with no-till, Koons said. "That's the way it should be. Some guys who rent don't care about taking care of their landowner's land."

Of course, things like lime mean more initial expense, and some landowners balk when they get the herbicide, pesticide, fertilizer and lime bills. But they're always pleased come harvest time, says Koons. "You just can't take short cuts with no-till" he emphasizes.

That means not skimping when it comes to weed and pest control. Koons figures $8 an acre is cheap insurance on a field that's worth $170.

To control pests, Koons applies Toxaphene with the fertilizer at the time of planting. The Pioneer hybrids are treated with fungicide and insecticide. He uses 16 pounds of Furadan per acre to protect against rootworm.

Koons usually plants in April. "As soon as we hit nice weather, we start planting. If the ground's ready we just keep planting. We don't have to stop."

To ensure proper planting, Koons uses a seed monitor. Watching it carefully, the monitor lets him know if the planter has gone awry.

Koons puts down up to 25 tons of manure per acre. "Liquid manure goes hand in hand with no-till," he says. It's important to cut down deep enough into the manure crust to let air and sunlight get down to the soil.

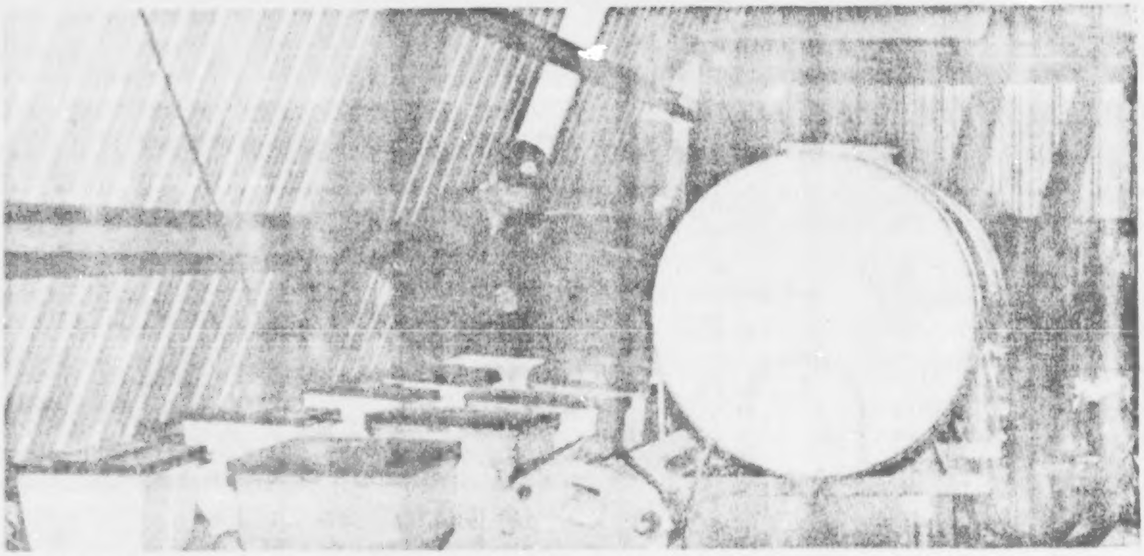
Weeds are controlled with 30" rows. This shades ground earlier, preventing weeds. "Anytime sun comes in, there are more weeds," says Koons.

Koons also uses Paraquat, a quart/acre on sod fields and a pint/acre on corn stalk fields. Atrazine and Princep are sprayed early, and Bladex is used as a follow up. When the plants are six to twelve inches, they are sprayed with a half a pint Banvel, and four ounces of 2-4-D to prevent broadleaves.

With all this fertilizer, insecticide and stubble sitting on top of the soil, the Ph may get a little low. Koons applies one ton of lime/acre every year, and soil tests every other year. The triazene herbicides won't work in an acid soil, and the nitrogen needs lime too. Koons likes to keep his soil at Ph 6.8 to 7.

No-till advantages show up at harvest time too, says Koons. "It's like running your equipment over a lawn compared to washouts and cultivator marks."

Rye acts as a winter cover for fields, on the Koons farm. It helps shade and mat the ground over winter, and the roots loosen the soil, making it easier for corn roots to penetrate.



Starting as soon as possible to plant corn in April, Koons uses a seed monitor when planting to ensure proper spacing.

He no-tills alfalfa into corn

Gayman saves his soil and time while maintaining top yields

By SUZANNE HALAS

>"No-till in alfalfa is really going to take off."

That's dairyman and Master Farmer Harold Gayman, Franklin County, talking about his no-till alfalfa seeded into corn stubble.

Harold's sold on the idea of no-till alfalfa, because for one thing, it saves time. "There's just one trip across the field," he says. That's especially important when Harold fall-seeds his alfalfa, and he's busy filling silo at the same time.

Also, he's found no-till alfalfa holds onto soil moisture better, and reduces erosion. "Since we no-till all of our corn, the only erosion we had was on the alfalfa stands," Harold says. Now 80% of his alfalfa is no-till.

No-till alfalfa also cuts down costs, the Pennsylvania Forage and Grassland Council president found. "I can't say no-till corn is cheaper, with chemical costs, but no-till alfalfa is definitely cheaper," he says. "The only cost with no-till alfalfa is the seed and one trip over the field."

Harold and sons Mark and Grant, in partnership with their father started no-tilling alfalfa into corn just one year ago, but so far they've been pleased with the results. "We haven't yield tested any of it, but it looks like its yields are just as high. I plan to enter that fall-seeded plot in this year's alfalfa growing contest, just to see how it does," he says. Last year, Gayman's contest plot yielded a whopping 6.2 tons to the acre.

Of top importance when seeding alfalfa no-till, is good planning, Harold says.

Planning starts, of course, with keeping soil at top fertility levels.

"The soil should be brought up to test recommendations at least six months before sowing," Harold says. "That way, nutrients will be available to the alfalfa when it's sowed."

But that's no problem for the Gaymans, who keep soil fertility high at all times, and maintain pH between 7.2 and 7.3 with a ton of lime every year.

Harold says that high pH keeps herbicides working best.

But, he adds, a farmer has to watch what kind of herbicides he uses on no-till corn he plans to seed alfalfa into.

This year Harold didn't use any trizene herbicides on corn he plans to rotate with alfalfa. A farmer should wait one or two years before planting alfalfa on trizene treated land, depending on the amount of chemicals used in the past. About 310 acres are in permanent no-till corn, and another 315 he rotates with alfalfa. Today, 475 acres are in corn and 150 in alfalfa.

Instead of trizene herbicides, this year Harold will spray his rotation corn with Bladex and Lasso or Dual.

Weed control on the alfalfa is handled two different ways, depending on when it's seeded.

If weeds are no problem come fall, the Gaymans will seed at that time.

While he hadn't seeded in the autumn for "some 20 years," Harold tried it last year, and was happy with the stand he got.

PENNSYLVANIA FARMER: May 9, 1981

"We got more tonnage the following year in a fall-seeded crop than we do in a spring seeded one," he says.

However, if there's a lot of broadleaf or fall pancium in the fields after corn harvest, Harold sprays with 2-4-D and paraquat. Of course, then he has to wait 21 days before seeding alfalfa.

In that case, Harold prefers to treat his field in the fall, and plant as soon as possible in the spring.

"We don't have time to wait three weeks in the fall," Harold says.

"We sow in spring as soon as we can get in the ground," he adds. That way, they're ahead of both the leafhopper and extra weeds. They can seed early in the year, because he's in south-central Pennsylvania, Harold reminds us.

In fact, one year, while the Gaymans were on vacation, their neighbors sowed alfalfa as early as February.

Even though leafhopper won't hit the new seedlings, Harold does treat his fields after first cutting. And, before that first cutting, he foliar sprays with Imidan or Parathion for weevil control with airplanes. "I don't like to drive through foot-tall alfalfa," he explains.

Harold seeds his crop with a Tye Drill, with eight-to ten-inch spacings. "It's a little wider than we like, but the yield is still just as good," he says.

This year his seeding rate is 20 pounds to the acre. "If we get a good stand, I may drop back to 15 pounds next year, and see how that works," he says. Penn State recommends 10 pounds to the acre.

Along with 20 pounds of alfalfa goes 1-1½ pounds of orchard grass. While Harold says the orchard grass cuts down on erosion with alfalfa, a heavier amount crowds out the alfalfa by the fourth year.

Because of lower yields during the fourth year of a stand, the Gaymans opt for a three-year rotation, putting the ground back in corn.

"We're looking for more tonnage; we need it," Harold says. He's speaking for 170+ registered Holsteins on test, and 170 more young stock.

Harold takes his cuttings every 32 days or so, depending on the weather. "We usually go out and cut when we see the first few blooms," says Harold.

All the hay, along with corn, goes into trench silos at the Gaymere farm.

While Harold is optimistic about no-till alfalfa, he says, "I'll be more comfortable if it works well this year."

STUDENT COMPETENCY SHEET

Module 6: Energy Conservation in Crops Production

Competency 2: Calibrate sprayers

Introduction:

In crop spraying as in medicine, just because a little bit does a lot of good doesn't mean that a lot will do better. Application of too much spray material wastes money and energy expended in producing the material. If too little is applied, however, crop yields may be reduced and energy, effort and money invested may be wasted.

Rate applied per acre depends on
...nozzle size
...field speed
...pressure
...viscosity of the liquid

Remember these relationships between flow rate and pressure: To double the flow rate, pressure must be increased four times; to halve the flow rate, pressure must be reduced to one-fourth the original pressure.

Resources and Equipment:

WVU Extension Circular PM-1.0, Calibration of Sprayers, or

Mechanics in Agriculture (Interstate Printers)

Film, "Pesticides: Fundamentals of Proper Application," available from Venard Films, Ltd. (13 minutes), and projector.

Field sprayers, calibrated container or fruit jars

Learning Activities:

1. Observe the film, "Pesticides: Fundamentals of Proper Application." Note methods of adjusting and regulating spray equipment and types of equipment recommended for various jobs.

2. Field calibrate a sprayer, following instructions for Method 1 presented in WVU Extension Circular PM-1.0, Calibration of Sprayers, or those included in Mechanics in Agriculture (Interstate). Carefully study the steps involved.

   Before calibration, check each nozzle tip for equal distribution:

   a. Install nozzles

   b. Partly fill sprayer tank with water

c. With sprayer stationary and operating at recommended pressure, collect spray from each nozzle tip with a calibrated container for an equal amount of time (15-30 seconds)

d. Record each sample and compare with the average

$$\text{Average} = \frac{\text{total liquid collected}}{\text{number of nozzles}}$$

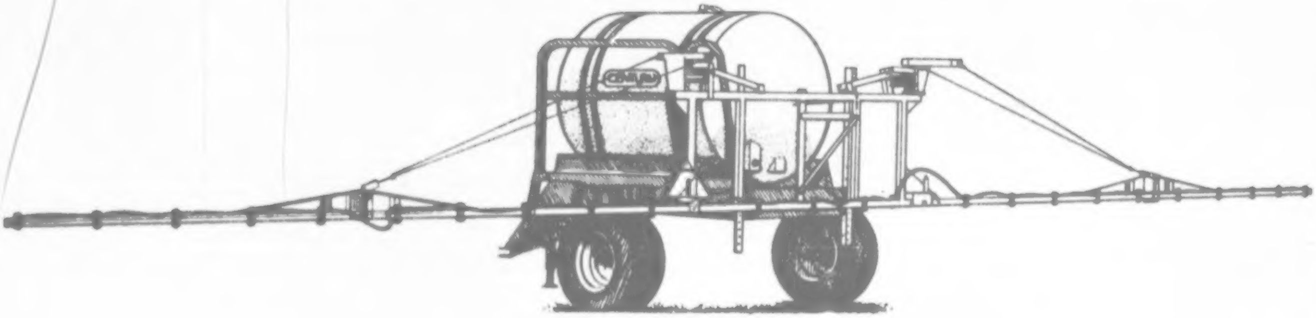
e. Replace any tip having an uneven spray pattern or an output 10 percent greater or less than the average

Evaluation:

You will calibrate a sprayer according to directions given in the reference used.

Note: Extensive information concerning selection, calibration and use of spraying equipment is also published in FMO Crop Chemicals and FOS Mowing and Spraying, both from John Deere.

Other practical information concerning pesticide usage can be found in WVU Extension Circular PM-7.1, Using Pesticides Efficiently.



COOPERATIVE EXTENSION SERVICE
WEST VIRGINIA UNIVERSITY

Agricultural Engineering

PM - 1

A. W. Selders

CALIBRATION OF SPRAYERS

Sprayers should be calibrated at the start of each spraying operation and frequently thereafter. The rate of application will be determined by the rate of discharge of the nozzles and the rate of forward speed. If the required size nozzles are used and are functioning properly at the required pressure, then the principle purpose of calibration is to determine the proper rate of forward speed. A tractor speedometer proves very useful in maintaining a uniform rate of travel.

Method 1

Essential steps in calibrating a sprayer are as follows:

1. Set two stakes 40 rods apart (660 feet).
2. Fill the sprayer tank with water. Operate the sprayer to be sure the entire supply line up to the shut-off valve is full before finally filling the tank and recording the water line on a measuring stick.
3. Drive the sprayer round trip between stakes (80 rods total) at the desired speed and with the sprayer in full operation. The sprayer should be moving at normal speed with pressure up and the discharge valve should be opened as the sprayer passes the first stake and closed as it passes the second stake in each direction. Mark the throttle setting.
4. Carefully measure the amount of water required to fill the tank after the test. Before refilling to the same mark on the measuring stick, be sure that the sprayer is in the same position as for the first filling or is resting level in both instances to avoid possible error.
5. Multiply gallons used to refill tank by 33 and divide by the width sprayed in feet. This gives gallons per acre applied.

Example: Assume it is desired to apply a spray material at the rate of 10 gallons per acre traveling at a forward speed of 5 mph with a boom covering a 20-foot width. If 5 gallons of water were required to refill the tank after the calibration, then the actual rate of application is determined as follows:

$$\text{gpa} = \frac{5 \times 33}{20} = 8.2 \text{ gallons per acre}$$

Since this rate of application is lower than desired, the forward speed must have been greater than 5 mph. Therefore, the test should be repeated using a throttle setting which will give a slightly slower rate of travel.

Method 2

Another way to calibrate the sprayer that might be easier and just as good is as follows:

1. Measure the width in feet which the boom covers. Allow for proper overlap.
2. Divide 43,560 (number of square feet in one acre) by the width covered. This will give the number of feet to travel to cover 1 acre. Example: Boom covers 20 feet; 43,560 divided by 20 equals 2178 feet. This is the distance to travel to cover 1 acre.
3. Measure off the feet needed to travel to cover 1 acre.
4. Fill the spray tank with water; be sure it is full up to the same point where it is normally filled.
5. Set the sprayer pressure exactly the same as used when actually spraying and travel down the course measured in Step 3.
6. Measure carefully the number of gallons of water needed to refill the tank.
7. The number of gallons required to fill the tank is the number of gallons the sprayer applies per acre.
8. Assume 10 gallons are needed to fill the tank. For each 10 gallons of water in the tank, add the amount of chemical recommended per acre.

Method 3

Use a calibrated measuring device. A 1-quart container made of clear plastic is strapped under one nozzle so the nozzle sprays into the container through an opening in the lid. The sprayer is then operated a measured distance, and the actual rate of spray is read at the level of the liquid on the container's calibrated sides.

TABLE 1 MINUTES TO SPRAY ONE ACRE AT VARIOUS SPEEDS AND BOOM WIDTHS*

Speed		Width Covered by Boom (Feet)						
MPH	Ft. per min.	10	15	20	25	30	40	50
2	176	24.8	16.5	12.4	10.0	8.3	6.2	5.0
3	264	16.5	11.0	8.3	7.0	5.5	4.1	3.3
4	352	12.4	8.2	6.2	5.0	4.1	3.1	2.5
5	440	9.9	7.0	5.0	4.0	3.3	2.5	2.0
6	528	8.3	5.5	4.2	3.3	2.8	2.1	1.5
7	616	7.1	4.7	3.5	2.8	2.4	1.8	1.4
8	704	6.2	4.1	3.1	2.5	2.1	1.6	1.2
9	792	5.5	3.7	2.8	2.2	1.8	1.4	1.1
10	880	5.0	3.3	2.5	2.0	1.7	1.2	1.0

*No allowance made for turning, filling, or servicing sprayer.

TABLE 2 TIME REQUIRED TO TRAVEL VARIOUS DISTANCES AT VARIOUS SPEEDS

Speed		100 Ft.	500 Ft.	660 Ft. (40 rds.)	1320 Ft. (80 rds.) (1/4 mi.)	2640 Ft. (160 rds.) (1/2 mi.)
MPH	Ft. per min.					
		min-sec.	min-sec.	min-sec.	min-sec.	min-sec.
1	88	1- 8	5-39	7-30	15- 0	30- 0
2	176	0-34	2-50	3-45	7-30	15- 0
3	264	0-23	1-55	2-30	5- 0	10- 0
4	352	0-17	1-25	1-53	3-45	7-30
5	440	0-14	1- 8	1-30	3- 0	6- 0
10	880	0- 7	0-34	0-45	1-30	3- 0

Arthur W. Selders

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567-R769 1072

COOPERATIVE EXTENSION SERVICE
West Virginia University
Center for Extension and Continuing Education

using pesticides efficiently

Agricultural Engineering

The petroleum shortage has extended to and affected to a great degree those who use pesticides or depend upon them. Petroleum derivatives are used as necessary raw materials in the production of almost 100 percent of modern pesticides used in the U.S. at present. Many other petroleum derived chemicals are also needed as intermediate products in manufacturing pesticides.

As a result of the petroleum shortage, the prices of needed agricultural chemicals have significantly risen in the last several years. To add further pressure to the cost of using pesticides, other industries outside agriculture have also needed the same fuels and the same intermediate and primary petroleum products that the pesticide industry must have.

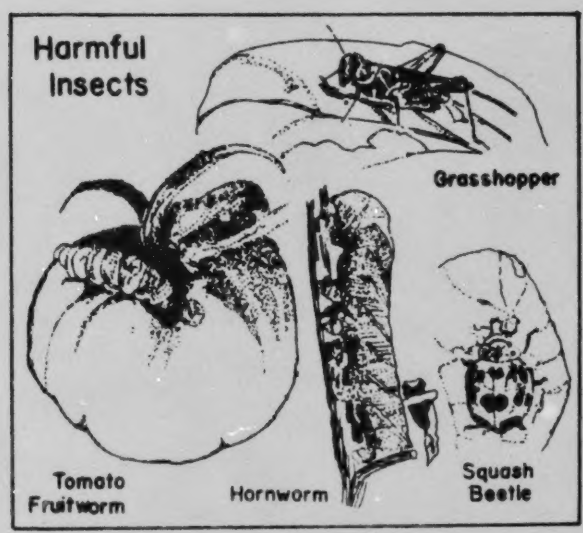
In applying pesticides, there is more to consider than just the cost of the material being applied. The farmer or user must consider these points: (1) the amount of fuel used to drive his equipment; (2) the price of labor used in making the application; (3) the cost of maintenance and overhead of the application equipment. In many cases, these three items far outweigh the cost of the pesticides being applied.

WHAT CAN BE DONE?

The success of many operations often revolves around the understanding and application of a few basic rules. In the use and application of pesticides, particularly insecticides, several basics become major concerns. These basics can be referred to as the 5 R's. They are:

(1) Use the Right insecticide for the job.
(2) Use the insecticide in the Right amount.
(3) Apply the insecticide in the Right way.
(4) Apply the insecticide at the Right time.
(5) Know the Right identification of the insect.

Insects left unchecked can destroy crops



A basic understanding and knowledge of these 5 R's is going to become more and more important if the modern day agriculturist is to be successful. Application of the 5 R's will result in more efficient use of energy since energy expended is directly related to the time and cost of production.

How can a pesticide user apply the 5 R's to his situation? The following outline will be helpful as an introduction, but each pesticide user must continually seek to understand these principles if he is to optimize his efficiency.

[illegible]

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West Virginia University and U. S. Department of Agriculture Cooperating

(1) - How is the Right material determined?

Many sources of information exist: (1) The county Cooperative Extension Service maintains up-to-date manuals, circulars and recommendations on specific crops and pests in your area and offers technical help. (2) Dealers and suppliers of pesticides have written information available. (3) Other farmers or peers in a specific area can offer advice. They can be contacted through growers' associations, etc.

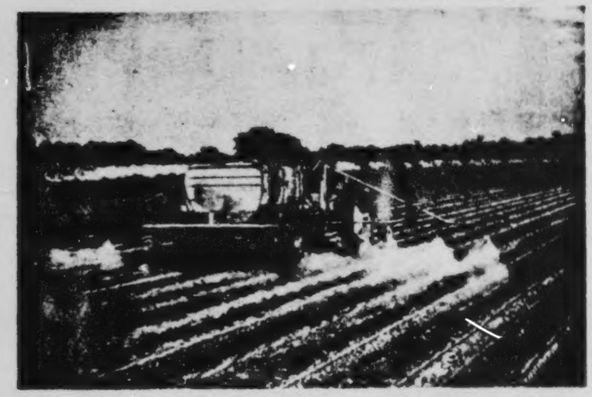
(2) - What is the Right amount?

The right amount also can be found from the same sources as listed in (1). Also, the label on the pesticide should be carefully read as being the best source of information on correct amounts. Use caution and do not overdose. If a little is good, a lot is not necessarily better. You could have a crop confiscated by the Food and Drug Administration or the State Department of Agriculture for overdosing. Penalties for overdosing can range from having to rewash crops to having the entire crop destroyed. Even rewashing can cause financial loss because of the time and labor involved. Perishability is also a problem when extra time is taken for rewashing.

In addition, be sure to buy proper measuring devices. Many errors can be made when small amounts are used.

(3) - What is the Right way?

This principle is probably the most often violated one of the 5 R group. This violation results in poor or no control, overdosing, wastage, and loss of energy, time and money. It is imperative to do several things. (1) Calibrate your spray equipment carefully and regularly. Remeber, a 10 percent error is magnified in time, money, and labor over an entire season. Instructions on how to calibrate can be obtained from your local County Extension Director or agricultural supply dealer. (2) Choose the proper equipment for the job and keep it clean. Use care in selecting good quality nozzles, strainers, discs and other items used in spraying. (3) Carefully adhere to the recommended uses of pressures and speeds. Remember, a slight increase in pressure or reduction in desired ground speed results in more spray used. (4) Constantly check for leaks in your system, and replace worn discs. A worn disc can apply a great deal more spray than you want. (5) Excessive speed in spraying is false economy. To have to do a job over because of failure to get control, costs twice as much in materials, labor and energy. In the meantime, the unprotected crop is subject to loss due to insect damage.



Grower applying pesticides

(4) - When is it the Right time for action?

This is probably the most difficult question to answer. It is best approached by becoming familiar with your particular crop and the pests specific to your area. It is necessary to obtain research information through the university systems or other research (via Cooperative Extension Service) on thresholds of damage that your crop can stand before you have economic loss. In the past, if one worm was seen, it was "one too many," and the sprayer was put into action. Pesticide shortage and costs prohibit this practice under present economic conditions. The grower is encouraged to do several things: (1) He should scout or examine each of his fields on a weekly or, better, on a twice weekly basis. (2) He should know his pests and their habits. He must consider whether pests are hurting his crop or just eating insignificant amounts of foliage. (3) He should attend growers' meetings and seek the latest information on how to scout particular crops. Haste in spraying can often be waste.

(5) - What is the Right name of the pest?

The grower can identify his own pests most of the time. Many states now have training sessions where the grower can learn. Bulletins and circulars put out by the Cooperative Extension Service have descriptions and photographs to properly aid the grower. If in doubt, the grower should contact his County Extension Director for proper identification. Recent research has shown that one species of worm cannot be treated as another species. Specific insecticides and specific amounts must be used for specific pests. Misindentification can lead to selection of the wrong material. Not only is the pest uncontrolled, it continues to damage a crop making repeat applications necessary. It is easy to see that costs can soon double or triple if pests are not identified correctly.

In addition to pesticides, much literature and training can be obtained in manipulating beneficial organisms in our environment to control pests. These beneficial organisms include types of mites, insects, numerous arthropods, friendly fungi and certain bacteria. These beneficial organisms prey on and destroy the harmful pests that destroy crops.

Today's grower is urged to use modern pest management. That is, he should use the correct varieties, consider planting times, use cultural techniques, spray only when needed, observe the 5 R's and destroy crop residues after harvest. This total approach to pest control is proving an effective way to reduce costs and energy inputs, increase yields, and provide the public with a better and safer product.

Arthur W. Selders

Arthur W. Selders, PE
Extension Specialist
Agricultural Engineering

STUDENT COMPETENCY SHEET

Module 6: Energy Conservation in Crop Production

Competency 3: Calibrate planting and fertilizing equipment

Introduction:

Time spent in calibrating equipment may be the most profitable hours of the year. Machines that apply improper rates not only can waste expensive seed and fertilizer but can cause reduced crop yields.

Your operators manual will indicate machine settings to obtain various application rates of different seeds and fertilizer materials. However, actual rates may vary because of machine wear, size of seed or fertilizer granules, and moisture content of the material. Better to be safe than sorry--check application rates before going to the field.

Resources and Equipment:

Grain drills, planters, fertilizer spreaders and attachments; scales; plastic sheet or canvas; tape measure; fertilizer; seed

WVU Extension Circular PM-1.1, Calibration of Drills and Planters

WVU Extension Circular PM-1.2, Seed Spacing Tables for Corn

WVU Extension Circular PM-1.10, Calibrating Lawn Spreaders

FMO Planting (John Deere) (optional)

Operators manuals for machines to be calibrated

Learning Activities:

Calibrate a planter and a fertilizer applicator from among the following:

1. Grain Drills and Fertilizer Applicators

To calibrate grain drills and fertilizer applicators, follow directions given in WVU Extension Circular PM-1.1, Calibration of Drills and Planters or FMO Planting(John Deere).

Be sure to refer to your operators manual for adjustment procedures.

Make notes of your calculations to turn in.

2. Row Crop Planters

Follow directions given in WVU Extension Circular PM-1.1, Calibration of Drills and Planters, PM-1.2, Seed Spacing Tables for Corn, or FMO Planting (John Deere).

Adjustment procedures can be found in your operators manual.

Make notes of your calculations to turn in.

3. Hand Operated Lime and Fertilizer Spreaders

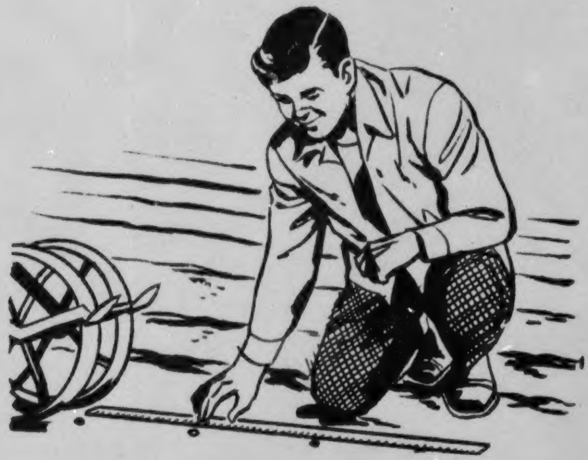
Follow directions given in WVU Extension Circular PM-1.10, Calibrating Lawn Spreaders.

These same directions can be applied in calibration of power operated cyclone (rotary) and gravity feed field spreaders.

Make notes of your calculations to turn in.

Evaluation:

1. Turn in your calculations in calibrating planters and fertilizer applicators.
2. You will accurately calibrate a planter and a fertilizer applicator appropriate for your occupational experience program, or for a farm in your community.



COOPERATIVE EXTENSION SERVICE
WEST VIRGINIA UNIVERSITY

Agricultural Engineering

PM - 1.1
E. B. Collins

CALIBRATION OF DRILLS AND PLANTERS

Occasionally drills and planters should be recalibrated to ensure the amounts of fertilizer deposited and the quantity of seed planted corresponds to the settings and amounts as indicated by the machine setting, or the farmers requirements. The change in planting rate usually results from wear in the moving parts of drills and planters, or rust and corrosion of the metering devices and feed tubes. Calibration may be required purely because the instruction manual has been lost. There are several methods of calibrating drills and planters but only two will be discussed in this information sheet.

Method I - Shop Test

Step 1. Jack up one wheel if the machine is driven by either wheel. If driven by both wheels, jack up both wheels.

Step 2. Remove each seed tube from its boot and place a container under each tube, i.e., a quart jar, coffee can, paper bag, etc. If individual amounts coming from each tube are not required, then use a plastic sheet or canvas to catch the grain.

Step 3. Measure the diameter of the drive wheel in feet and multiply by 22/7. This will be the length around the outside of the wheel (circumference). If you have a flexible rule, the distance around the wheel can be measured directly. This length measurement represents the distance traveled on the ground when the wheel has completed one revolution.

Example: If the diameter of the wheel was 2 1/2 feet, the circumference would be 7.85 feet.

Step 4. Divide the width of the drill or planter (measured in feet) into 43,560 - which is the number of square feet in one acre. The answer to this calculation represents the distance the machine must travel to plant one acre. The width of the machine (drill or planter) is determined by multiplying the distance between the feed tubes by the number of feed tubes. Express the width in feet.

Example:

Ten (10) feed tubes with a 12 inch spacing represents a 10 foot planting width. The distance traveled to plant one acre would be:

$$\frac{43,560 \text{ sqft/acre}}{10 \text{ ft width}} = 4,356 \text{ feet}$$

Step 5. Divide the circumference of the wheel from Step 3 into the distance the machine must travel to plant one acre from Step 4. This answer represents the number of revolutions the wheel must make to plant one acre.

Example:

$$\text{Revolutions/acre} = \frac{4,356 \text{ ft travel/acre}}{7.85 \text{ ft circumference of wheel}} = 554.9 \text{ revolutions/acre}$$

Step 6. Mark one wheel with a vertical line and rotate it one-tenth the number of revolutions necessary to plant one acre.

Example:

$$\text{Number of revolutions} = \frac{554.9}{10} = 55.5 \text{ revolutions/test}$$

Step 7. If the output of each feed tube is caught, note any discrepancy in the amount of seed dropped. If a difference in amounts occur between the feed tubes, check the feeding and metering devices.

Step 8. Dump the contents of each small container into one large container or collect that fallen on the canvas or plastic sheet and weigh or measure its volume, whichever is required. Multiply these figures by ten to equal an acre equivalent and compare these values with your requirement or the operator's manual specification for the unit. If the amounts are not correct, make the necessary adjustment on the machine and test again. The procedure is the same for both seed and fertilizer calibration.

COOPERATIVE EXTENSION SERVICE
WEST VIRGINIA UNIVERSITY

Agricultural Engineering

PM - 1.2
K. C. Elliott

SEED SPACING TABLES FOR CORN

These tables are used to determine seed spacing in order to obtain the desired plant population per acre.

1. Decide what plant population is desired and turn to the appropriate table.

Table	Plants per acre
I	16,000
II	18,000
III	20,000
IV	22,000
V	24,000

2. Find the percent germination of the seed on the tag of the seed corn bag and locate this percent on the left column of the table.

3. Select the row spacing of your planter at the top of the table.

4. Read the percent germination across the table to the column with the proper row spacing. This is the number of inches between seeds. These numbers have been rounded to the nearest quarter of an inch.

5. Adjust the planter to give this distance. Refer to the planter manual to make these adjustments.

6. After making the proper adjustments, set up a test run. Run the planter a distance of 10 feet. Divide the number of seeds dropped into 120. This gives the number of inches between seeds. It is advisable to make three test runs and use the average number of seeds dropped.

Tables and formulas compiled by William C. West, Agricultural Education Graduate Student, and Donald E. Zimmerman, Animal Science Senior, for Agricultural Mechanics 253. April 1974.

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TABLE I - 16,000 PLANTS PER ACRE

% Germ.	Row Spacing 30"	32"	34"	36"	38"	40"
100	13	12 1/4	11 1/2	10 3/4	10 1/4	9 3/4
99	13	12	11 1/2	10 3/4	10 1/4	9 3/4
98	12 3/4	12	11 1/4	10 1/2	10	9 1/2
97	12 3/4	11 3/4	11	10 1/2	10	9 1/2
96	12 1/2	11 3/4	11	10 1/2	10	9 1/2
95	12 1/2	11 1/2	11	10 1/4	10	9 1/4
94	12 1/4	11 1/2	10 3/4	10 1/4	9 1/2	9 1/4
93	12	11 1/4	10 3/4	10	9 1/2	9
92	12	11 1/4	10 1/2	10	9 1/2	9
91	11 3/4	11	10 1/2	10	9 1/4	9
90	11 3/4	11	10 1/4	10	9 1/4	8 3/4

TABLE II - 18,000 PLANTS PER ACRE

% Germ.	30"	32"	34"	36"	38"	40"
100	11 1/2	10 3/4	10 1/4	9 1/2	9 1/4	8 3/4
99	11 1/2	10 3/4	10	9 1/2	9	8 1/2
98	11 1/4	10 1/2	10	9 1/2	9	8 1/2
97	11 1/4	10 1/2	10	9 1/4	9	8 1/2
96	11	10 1/2	9 3/4	9 1/4	8 3/4	8 1/4
95	11	10 1/4	9 3/4	9 1/4	8 3/4	8 1/4
94	11	10 1/4	9 1/2	9	8 1/2	8 1/4
93	11	10	9 1/2	9	8 1/2	8
92	10 1/2	10	9 1/2	9	8 1/2	8
91	10 1/2	10	9 1/4	8 3/4	8 1/4	8
90	10 1/2	9 3/4	9 1/4	8 3/4	8 1/4	8

TABLE III - 20,000 PLANTS PER ACRE

% Germ.	Row Spacing 30"	32"	34"	36"	38"	40"
100	10 1/2	9 3/4	9 1/4	8 3/4	8 1/4	7 3/4
99	10 1/4	9 1/2	9	8 1/2	8 1/4	7 3/4
98	10 1/4	9 1/2	9	8 1/2	8	7 3/4
97	10	9 1/2	9	8 1/2	8	7 1/2
96	10	9 1/2	8 3/4	8 1/4	8	7 1/2
95	10	9 1/4	8 3/4	8 1/4	7 3/4	7 1/2
94	9 3/4	9 1/4	8 1/2	8 1/4	7 3/4	7 1/4
93	9 3/4	9	8 1/2	8	7 3/4	7 1/4
92	9 1/2	9	8 1/2	8	7 1/2	7 1/4
91	9 1/2	9	8 1/4	8	7 1/2	7
90	9 1/2	8 3/4	8 1/4	7 3/4	7 1/2	7

TABLE IV - 22,000 PLANTS PER ACRE

% Germ.	30"	32"	34"	36"	38"	40"
100	9 1/2	9	8 1/2	8	7 1/2	7 1/4
99	9 1/2	9	8 1/4	7 3/4	7 1/2	7
98	9 1/4	8 3/4	8 1/4	7 3/4	7 1/4	7
97	9 1/4	8 3/4	8	7 1/2	7 1/4	7
96	9 1/4	8 1/2	8	7 1/2	7 1/4	6 3/4
95	9	8 1/2	8	7 1/2	7 1/4	6 3/4
94	9	8 1/2	7 3/4	7 1/2	7	6 3/4
93	8 3/4	8 1/4	7 3/4	7 1/4	7	6 1/2
92	8 3/4	8 1/4	7 3/4	7 1/4	7	6 1/2
91	8 1/2	8	7 3/4	7 1/4	6 3/4	6 1/2
90	8 1/2	8	7 1/2	7	6 3/4	6 1/2

TABLE V - 24,000 PLANTS PER ACRE

% Germ.	Row Spacing 30"	32"	34"	36"	38"	40"
100	8 3/4	8 1/4	7 3/4	7 1/4	7	6 1/2
99	8 1/2	8	7 3/4	7 1/4	6 3/4	6 1/2
98	8 1/2	8	7 1/2	7 1/4	6 3/4	6 1/2
97	8 1/2	8	7 1/2	7	6 3/4	6 1/4
96	8 1/4	7 3/4	7 1/4	7	6 1/2	6 1/4
95	8 1/4	7 3/4	7 1/4	7	6 1/2	6 1/4
94	8 1/4	7 3/4	7 1/4	7	6 1/2	6 1/4
93	8	7 1/2	7	6 3/4	6 1/2	6
92	8	7 1/2	7	6 3/4	6 1/4	6
91	8	7 1/2	7	6 3/4	6 1/4	6
90	7 3/4	7 1/4	7	6 1/2	6 1/4	6

Arthur W. Selders

Arthur W. Selders, PE
Extension Specialist
Agricultural Engineering

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COOPERATIVE EXTENSION SERVICE
West Virginia University
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calibrating lawn spreaders

Agricultural Engineering

Many lawn product manufacturers provide a handy chart to inform homeowners of the recommended setting for some of the popular makes of lawn or "fertilizer" spreaders. If the spreader is new or has been maintained in good condition, these recommendations are probably accurate.

The determination can be confirmed by measuring your lawn area and applying the recommended amount of material as directed on the label. However, as the spreader wears or is misused, it will need calibrating to ensure that any lawn product is applied according to recommendations.

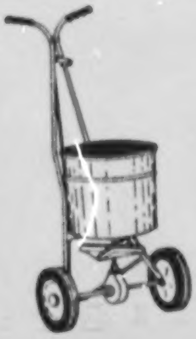
Dry lawn products such as fertilizers, lime, herbicides, insecticides and fungicides are manufactured in grades with varying particle size and density. A different setting is needed for each material and spreader. The only sure way to provide the correct setting for an accurate, uniform application is to calibrate the spreader. The two types of lawn spreaders are the gravity or drop and the centrifugal or rotary.

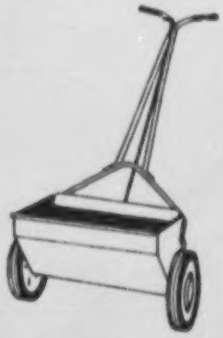
Gravity or Drop Spreader

1. Make a trial application of material over a known area such as 200, 500 or 1,000 square feet. The larger the area the more accurate the calibration test will be. Measure this off in a convenient manner to conform to the width of your spreader coverage. If your spreader covers a 24 inch width, measure a strip of area 2 feet by 100 feet or 4 feet by 50 feet, or any larger area in increments to fit your spreader width and lawn area.

2. Attach a strip of plastic or canvas, a V-shaped trough made from stiff cardboard, wood, sheet metal or a piece of eave trough under the spreader to collect the material during the trial run.

3. Most products carry recommendations in pounds per 1,000 square feet. Determine the approximate amount of the material needed for your trial area. Weigh out this amount plus a few pounds more. In the case of 500 square feet, this is one-half





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of 1,000 square feet. If the recommendation calls for 10 pounds of produc per 1,000 square feet, weigh out 7 to 8 pounds. If the recommendation does not come out to even pounds, convert to ounces by multiplying tenths by 16 to convert to ounces. Thus 4.8 pounds would convert to 4 pounds, 13 ounces (rounded to the nearest ounce).

4. Close the spreader hopper and place the material in the hopper. Set the spreader opening to the recommended setting. If there is no recommendation, you'll have to guess at a setting. Be sure to spread the material evenly in the spreader. When you start the trial, open the spreader and walk at a normal pace to the end of the area. Be sure to shut the spreader off during the turn around if you have to return to complete the measured area. Keep watch on the contents in the spreader to be sure you do not run out before you cover the trial area. Overlap the wheel tracks properly so the width covered is the actual coverage width of the spreader.

5. The material collected is then weighed and application rate calculated. For example, with a trial area of 500 square feet and 7.5 pounds of material collected, the application rate per 1,000 square feet would be 15 pounds. Since the recommended rate was 10 pounds per 1,000 square feet, adjust the spreader setting and repeat runs until the recommended amount is obtained.

Centrifugal Spreader

To calibrate a centrifugal or rotary type spreader measure the effective width of application of the particular material, since material can differ from a spread of 3 to 4 feet up to a spread of 6 to 8 feet. Allow for overlapping by about 20 percent and use this width to determine the total trial area. Once this width is determined attach a plastic or other type bag to the spreader so the spinner is free to rotate and throw out the material. Use the same procedure as described above to establish an accurate spreader setting.

Important Points When Calibrating Spreaders

** Measure your lawn and determine the total area so that you can buy the right amount of material.

** Read the label and be sure to follow instructions and precautions.

** Rotary spreaders require special observation with each product because different densities spread at different widths.

** When using rotary spreaders be sure to overlap the edges by at least 20 percent.

** When you have accurately calibrated a product to your spreader, be sure to record both the particular product and the spreader setting so you won't have to repeat the procedure again. A piece of paper taped to the garage wall may be a handy place to note this information.

** Once you have finished using a spreader, wash it out with water. After it has dried, apply a light coating of oil or some other rust preventive.

** Do not apply any fertilizer product when the grass is wet.

** Granular herbicides are usually applied to moist grass.

Arthur W. Selders

Arthur W. Selders, PE
Extension Specialist
Agricultural Engineering

STUDENT COMPETENCY SHEET

Module 6: Energy Conservation in Crops Production

Competency 4: Conserve energy through reduced fertilizer requirements

Introduction:

Manufacture of nitrogen consumes 95 percent of the energy used in fertilizer production, whereas manufacture of phosphate and potash fertilizers uses only 5 percent. The reason? Phosphate and potash fertilizers are mined; nitrogen is made from natural gas.

Reducing the amount of fertilizer applied while maintaining crop yields would increase profits and conserve energy. Fortunately, there are some ways to reduce the need for commercial fertilizers with no loss of yield. You will become acquainted with some of them in this lesson.

Resources and Equipment:

WVU Extension Circular PM-7.2, Proper Fertilizer Management Saves Energy

University of Delaware Bulletin No. 120, NO-TILLage (copy found following Module 5, Competency 1)

A crops production textbook

FMO Crop Chemicals (John Deere) (optional)

Learning Activities:

1. Read the following:
    a. WVU Extension Circular PM-7.2, Proper Fertilizer Management Saves Energy
    b. University of Delaware Bulletin No. 120, NO-TILLage
    c. The chapter(s) in your crops production textbook regarding cover or green manure crops
2. Answer the following questions:
    a. How can soil testing be used to conserve fertilizer?
    b. How does soil pH influence availability of fertilizer elements?
    c. What types of crops can take nitrogen from the air and fix it in the soil?

d. How can the use of cover crops (green manure crops) save fertilizer?

e. What are some appropriate winter cover crops for use in your community?

f. When should cover crops be planted?

g. Bonus Questions:

How can fertilizer placement reduce fertilizer usage?
How is it done?
What fertilizer elements should be banded (placed), if possible?

(If you need help answering these questions, study the appropriate section in your crops textbook, in FMO Crop Chemicals (John Deere), or in other available references.)

Evaluation:

1. Turn in answers to questions in Learning Activity #2.
2. Outline a plan for conserving fertilizers in a crop grown as part of your occupational experience program, or for a crop commonly grown in your community. Turn in for grading.

TESTING YOUR SOIL
HUNGER SIGNS
CROPPING HISTORY
TISSUE TEST

COOPERATIVE EXTENSION SERVICE
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proper fertilizer management saves energy

Agricultural Engineering

INTRODUCTION

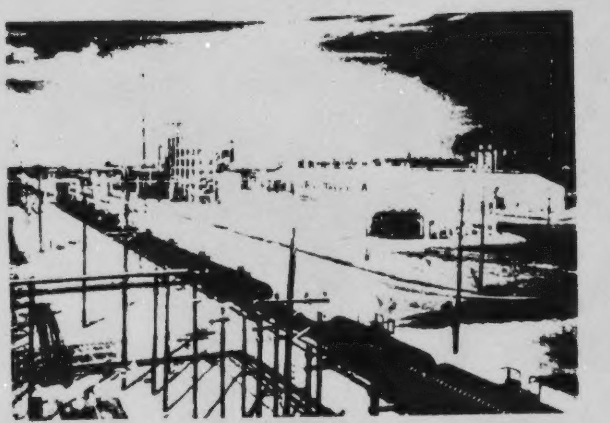
Agriculture and food systems use about 13 percent of the total U.S. energy consumption which (in 1970) represented 4,667 trillion Btu (British thermal units) of fossil fuel energy. The fertilizer industry, the heaviest energy consumer of agricultural manufacturing industries, used 504 trillion Btu, accounting for 12 percent of the Btu for agriculture and 1.55 percent of our total energy consumption.

FERTILIZER INDUSTRY

A total of 479 trillion Btu, 95 percent of the total used in fertilizer manufacturing, was consumed in the manufacture of nitrogen fertilizer materials in 1972-73 (Table 1). Natural gas is the primary fossil fuel used to produce anhydrous ammonia, a nitrogen fertilizer, accounting for 96 percent of the 40.9 million Btu needed to produce a ton of this product. Ammonia is the basic source of nitrogen for fertilizer purposes. Ammonia is used directly in crop production and in manufacturing urea, ammonium nitrate, sodium nitrate, calcium nitrate and ammonium sulfate. On the other hand, the manufacture of phosphate and potash materials consumed approximately 5 percent of the total energy used in manufacturing fertilizer materials.

Table 1. Energy Requirements to Produce Selected Fertilizer Materials in 1972-73

Materials	Btu per ton (thousands)	Tons of final product (millions)	Total Btu (trillion)
Nitrogen (N)	21.5	22.3	478.8
Phosphate (P_2O_5)	0.9	14.6	13.7
Potash (K_2O)	2.1	5.2	11.0
Total			503.5



Fertilizer plants such as this one depend largely on fossil fuels.

FUTURE IMPLICATIONS

Total energy requirements for selected fertilizer materials are projected to increase by 17 percent to 591 trillion Btu in 1980. With natural gas reserves decreasing, the fertilizer industry will be forced to seek other sources of feed stock (raw materials) and non feedstock energy.

Use of any known sources of hydrogen feedstock other than natural gas results in significant increases in production cost of nitrogen (Table 2). Naphtha

Table 2. Raw Materials Cost Portion for Ammonia Production

Raw material (feedstock)		Production Cost	
Amount required per ton Ammonia	Cost of feedstock per unit	Raw material cost/ton NH_3 $/ton	Production cost/ton NH_3 $/ton
Natural gas 38,500 MSCUFT*	1.50 MSCUFT	57.75	91.00
Naphta 0.88 ton	69.25/ton	60.94	98.00
Heavy oil 0.965 ton	63.50/ton	61.28	103.00
Coal 2.2 ton	42.00/ton	92.40	150.00

*MSCUFT = 1000 standard cubic feet

and heavy oil reserves are finite. With present technology, coal appears the most likely future feedstock. At the present cost of coal, this could result in a 65 percent increase in production cost of ammonia.

This increase will be passed on to the farmer in the form of higher fertilizer prices. Therefore, to conserve energy sources and maximize profit from a farming operation, we must seek ways of improving the efficiency of the fertilizer we use.

IMPROVING FERTILIZER EFFICIENCY

There are several ways we can improve the efficiency of the fertilizer.

Soil Testing

Optimum economic fertilization is a must and can best be accomplished by a well-planned soil testing program. By taking a representative soil sample of the area to be farmed and having it analyzed for primary plant food nutrients, you can plan your fertilizer and liming program and apply the recommended rate of only those plant nutrients which were shown to be deficient by the soil test.

In many cases, a properly followed soil testing program will result in more efficient use of the energy available fertilizers. County Extension offices can offer assistance in taking soil samples.

Following a soil testing program helps reduce fertilizer requirements.

Use of Lime

The proper use of lime can have a very significant effect on fertilizer utilization. Over liming can reduce nutrient availability and be as detrimental as under liming. Most of the essential plant nutrients increase in solubility and availability as the soil reaction is increased from pH 5.0 to 6.5 by liming. This increase in availability with liming promotes more efficient utilization of both native soil fertility and added fertilizer nutrients.

The solubility of phosphorus compounds in the soil is acutely affected by soil pH. Under acid conditions (low pH), phosphorus is precipitated as iron and aluminum phosphates which are relatively insoluble and unavailable. With liming, phosphorus compounds become more soluble and could potentially reduce the need for phosphorus fertilizer.

Micronutrients, such as manganese, may be present in large quantities and become toxic to plant growth under acidic conditions. Proper liming decreases the solubility of manganese compounds and, therefore, reduces the potential toxicity.

The capacity of a soil to absorb cationic nutrients is referred to as the cation exchange capacity. The exchange of our soils comes mostly from Kaolinitic clay and organic matter. Soil reaction (pH) has a significant effect on the exchange capacity of these two soil components. As the soil pH increases, the number of active exchange sites on these two materials increases. This increase in exchange capacity is important in the retention of fertilizer nutrients such as calcium, magnesium, ammonium, and potassium, against leaching losses.

The leaching loss of K (potassium) was reduced by 27 percent by liming a Norfolk fine sandy loam (Table 3) making more K available to the crop throughout the growing season and increasing the utilization efficiency of the potassium fertilizer.

Table 3. Effect of Liming on Leaching Loss of Potassium.

Soil	Percent of K held on exchange sites	
	Acid	Limed
Norfolk fine sandy loam (C.E.C.* 2-5 meq/100g)	22	49
Cecil clay loam (C.E.C. 10-12 meq/100g)	60	89

*C.E.C. = Cation Exchange Capacity

Use of Legumes

An outstanding characteristic of legumes is their ability to obtain N (nitrogen) from the air. Legumes, whose roots live in the soil with bacteria known as Rhizobium, are able to convert atmospheric N to a form which can be used by the plant. Therefore, cultivation of legumes has the double advantage of producing a valuable crop with the addition of little or no N fertilizer. While this fact has been known for decades, it is now more economically feasible to utilize legumes because of the rising cost of nitrogen fertilizers.

Most cultivated legumes will fix 150-400 pounds of nitrogen/acre/year.

Legumes vary in their ability to "fix" nitrogen. However, most cultivated legumes will "fix" 150-400 pounds of N/acre/year. The "fixed" nitrogen may be incorporated in the soil as a green manure for subsequent crops.

Research has shown that the amount of N contained in legume-grass forage was approximately equal to that in grass forage with 400 pounds of N/acre/year applied. At 20¢/pound of N, this would result in a savings of about $80/acre/year to a farmer and a considerable savings of energy used in the production of nitrogen fertilizer on a national basis.

Other Crop Management Practices

Selecting the best adapted variety for your cropping area can result in the maximum potential production of the crop and a higher return per pound of fertilizer consumed. Fertilizer placement and time of application can also increase effectiveness and utilization of applied fertilizer.

Type of Fertilizer Material Used

High analysis or concentrated fertilizer materials require more energy to produce on a per pound of nutrient basis than low analysis materials; however, the savings in energy used in transporting and applying these high analysis materials may make them more economical to use. Also the salt index of low analysis materials is lower, which reduces the salt burn potential.

The development and use of slow release materials which follow the nutrient requirement of the crop and avoid leaching losses can also aid in reducing the amount of fertilizer applied per unit of yield.

CONCLUSION

Your county Extension office can help with local recommendations on adapted varieties, rates of fertilizer applications and suitable fertilizer formulas.

With the impending energy shortage, especially in natural gas, we should make every effort to conserve the use of fertilizers. By using wise management practices, we can increase yield per pound of fertilizer with no decrease in profit. Furthermore, some of our fossil fuel energy resources will be conserved for a future generation.

STUDENT COMPETENCY SHEET

Module 6: Energy Conservation in Crops Production

Competency 5: Reduce energy consumed in drying grain

Resources and Equipment:

"Small Farmer Saves Big with Solar Grain Drying," an article in Pennsylvania Farmer, August 8, 1981.

Learning Activities:

1. Read and react to the following discussion of grain drying possibilities:

Grain drying is an energy intensive operation. Of crops which require drying, corn uses the most energy. It is our largest grain crop produced and is normally harvested with more excess moisture than any other grain.

Corn matures in the fall and is subject to serious field losses if not harvested before winter. Early harvest also allows a cover crop to be planted for soil protection and nitrogen production (if a legume is grown) over winter. The growing practice of double-cropping may require artificial drying of the crops to make the system work; for example, corn followed by winter oats; soybeans followed by wheat.

The least field loss occurs if corn is harvested at 20 to 25 percent moisture. For long term storage, moisture content must be reduced to 12-13 percent.

LP gas (butane or propane) and natural gas are the most commonly used fuels for grain drying, with electricity used primarily to operate dryer fans. It takes approximately 15 cubic feet of natural gas or 0.12 gallons of LP gas to dry a bushel of corn from 25 to 15 percent moisture, an acceptable level for short term storage or marketing. In the U.S., corn drying requires the equivalent of about 640 million gallons of LP gas each year. About one billion gallons are used in drying all crops.

How can energy requirements for drying the corn crop be reduced? Keep in mind conditions on your own farm or farms in your community as you study alternatives discussed below.

1. Plant varieties that will mature in 100 to 105 days. Solar heat and wind works in the field to dry corn prior to harvest. Later maturing varieties have less time to field dry.

2. Plant as early as possible regardless of variety. The earlier corn is planted, the earlier it will mature. More time is then available for field drying. Soil temperature should be 50 degrees F. at planting depth for germination to occur.

3. Delay harvest as long as possible. The longer the crop remains in the field, the dryer it will be. However, later harvest may result in greater lodging, ear dropping and harvest difficulty. Some field loss can be recovered by allowing livestock to clean up fields after harvest. Adverse weather risks are greater with delayed harvest, and cover crop planting may be difficult. Early November is probably the latest to begin harvest.

4. Harvest and handle as ear corn. Ear corn may be stored in cribs at moisture levels up to 25 percent. Temporary cribs can be made of snow fence or wire mesh. If corn is to be fed to cattle, corn and cob meal has greater feed value than grain alone.

5. Harvest and sell wet shelled corn. You're likely to take a beating with this alternative, but not always. Carefully consider (1) cost of drying, (2) buyer's moisture discounts, and (3) anticipated seasonal price rise.

6. Store wet shelled corn. But store wet corn only if you're going to feed it. Your alternatives are (1) shelled corn silage (moisture content should be 28-30 percent, grind as corn is put in silo or as it is taken out to feed); (2) treatment with propionic acid which allows safe storage for up to one year (but requires treatment equipment and wooden bins--acid will destroy metal bins).

7. Dry the corn, but don't overdry. Substantial savings can be realized by drying to 14 to 16 percent moisture rather than 12 to 13 percent. With proper aeration management, corn can be stored year-round at 14 percent moisture; corn at 16 percent can be kept until June or July of the following summer. If any corn is to be sold, there's no advantage to reducing moisture content below 15 percent.

8. Consider potential of fuel-less dryers. Solar dryers are cheap to construct and use. Since they raise air temperature only 5 to 15 degrees, it takes considerably more time for drying than with high temperature, high speed systems. If you're in a hurry, don't bother with this alternative; if you want to reduce costs and save energy, it's worth investigation.

In this Learning Activity, eight ideas have been presented, ideas which might be considered in reducing cost and energy consumption in corn drying. Can you think of others?

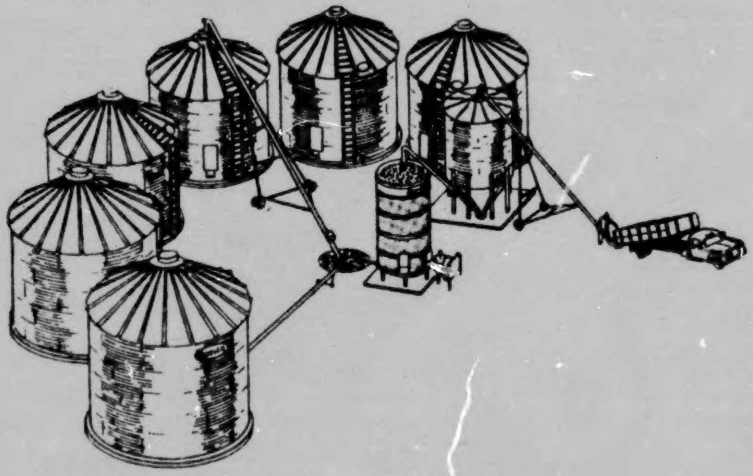
Discuss feasibility of these various alternatives with your classmates and teacher.

2. Read the article, "Small Farmer Saves Big with Solar Grain Drying," Pennsylvania Farmer, August 8, 1981. Discuss with your teacher and classmates the potential of such a system in your community.

3. Take a field trip to your farm or one in your community where grain drying is taking place. Determine cost per bushel for drying and suggest ways to make the operation more economical in terms of money and energy usage.

Evaluation:

Prepare a written report of practical specific management plans for reducing energy needs in drying grain on your farm or one in your community. Turn in to your teacher for grading.



Small farmer saves big with solar grain drying

By CURT HARLER

>Arthur K. Wert has 369 reasons for liking solar corn drying—each reason worth a dollar he saved drying his 1980 corn crop.

In addition to saving money drying grain, this Union County, Pa. livestock farmer also is able to cut his home hot water heating bill $1.50 to $2.00 per week by using the same solar equipment he uses to dry grain.

Wert realized these savings despite the fact last year he had only a bit more than half a corn crop to dry, and despite the small size of his family which makes the solar water heating less efficient than with a larger family.

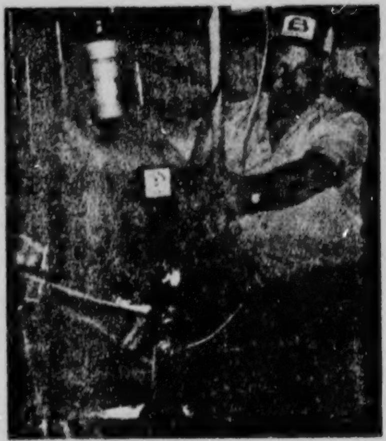
Both Wert and the Pennsylvania Power and Light Company of Allentown agree a solar program like that on Arthur's farm could be the answer to the problem of rising costs of fuels and risk of future scarcity.

"I'm really sold on it from the money savings alone," Arthur says.

The project began over a year ago when PP&L approached Wert to ask whether he'd like to participate in a study to see whether low temperature solar corn drying would work for a typical farmer in central eastern Pennsylvania.

Wert farms 88 acres, including 50 in corn, 10 oats, 8 wheat, and the balance in hay. Grain is kept on the farm to feed the steers and hogs he raises for market.

Two researchers take readings from the 530 square feet of collector as the paired units gather solar power to dry grain stored in bin behind. Units are different sizes because different types of solar panel were used.



Arthur Wert, Union County, Pa. poses in front of his hot water collector. Unit is a bonus from his solar grain drying system and warms the farm house's well water by 45 to 60 degrees during the 11 months when he is not drying grain.

For research purposes, PP&L supplied all the materials needed to make two portable solar collectors plus a number of gauges to study collector efficiency.

The units were constructed according to plans from the University of Illinois. Solar collector sizes are 12 feet by 24 feet and 10 feet by 24 feet. The smaller one was modified to pre-heat domestic hot water.

Wert figures it took about 50 man hours to construct the two solar collectors and get them

PENNSYLVANIA FARMER: **August 8, 1981**

ready to work. He had plenty of help in the project from the FFA boys at Mifflinburg High School.

Wert decided to connect the two solar units to an existing Stormor grain bin rated at 6,250 bushels capacity. He had used the bin for in-bin drying with an LP gas in past seasons.

But Wert had such confidence in the solar system that he sold his LP gas dryer before the solar system was completed.

There was nothing complex about constructing the solar unit, Wert says. Basically it is a system of 2x4s and plywood, a couple of pounds each of 8d and 16d nails, the fiberglass solar panels, and some black paint.

The system depends on drawing outside air into the top of the solar collector as shown in the accompanying pictures. Air is drawn into the long sloping portion of the collector through a 3½ inch space created by two 2x4s being nailed together. The air is thus exposed to the radiant heat of the sun through the 4-foot wide solar panels which are on the front of the collector.

The plywood backing behind the solar sheets is painted black for maximum heat absorption. The solar collector, of course, faces south.

The warmed air is sucked out the very bottom of the collector and into a large triangular space behind the solar panel. From there a 5 hp 24-inch fan rated at 10,000 cubic feet per minute draws the warmed air into the duct which takes it into the bin, up through the perforated bin floor, and so on through the grain.

"The system really is quite simple. It was not at all hard to build," Arthur says.

Total cost for all materials was about $2,000. That includes the 400 feet of half-inch copper tubing used in the collector which doubles as a hot water heater for the home. Figure does not allow anything for labor to build the unit.

Although the hot water heating panel is slightly smaller than the air panel, both are constructed identically. Size difference is due to PP&L's desire to try out two different types of solar panel which come in different sizes.

Both units are used in tandem to dry grain. The hot water unit is moved on penta-treated skids over to the farm house when grain drying is completed.

The hot water unit has about 400 feet of half-inch copper tubing attached to the plywood behind the solar panel. Like the plywood, the copper is painted black. The tubing stays in place when the unit is used to dry grain and is hooked to the home water supply when drying is finished.

Well water is drawn from underground into a special tank which has an inner and outer core. Cold water is kept in the inner core. From there it is circulated through the solar panel.

On a good solar day the water temperature jumps to about 130 degrees after a trip through the solar collector and into the outer tank.

From the inner tank the water goes to a standard hot water heater where the temperature need be raised only a few degrees, rather than the whole way from 56 degrees to 145 degrees.

Even on an overcast day the solar panels provide water preheated to about 95 degrees, although the outside air temperature may be 20 degrees lower, or dense clouds threaten rain.

Both Wert and PP&L Researchers Dick Hampsher and D.R. Bowersox kept close tabs on how the system worked.

> *"The system really is quite simple. It was not at all hard to build."*

Results were quite impressive.

Wert normally used 310 gallons of LP gas to dry corn. At current costs of 86¢ per gallon, his fuel cost would have been $267 plus $102 for electricity — a total of $369. With solar his harvest costs dived.

All of the grain was custom combined in two days, October 2 and 3. It took 29 more days to dry the grain to stable storage level.

Wert kept close records on the grain moisture. At least one moisture sample was taken from each field. Highest moisture going into the bin was 29%, lowest 18%. Average moisture was 27%. Corn was dried down to 14%.

Figured on a per bushel basis, cost of solar drying was 5¢ versus 9¢ with LP gas. Total non-solar energy used was 1.17 kilowatt hours per bushel.

But Wert got "free" 18,188,841 btu's collected in his panels. This despite an average daily air supply temperature high of 74.1 degrees, and an average ambient air temperature of only 65.6 degrees.

Results inside the farmhouse are just as impressive. He and his wife Ruth are saving 4 to 5 kwh electricity every day they use the solar hot water heating system. At PP&L's current rate of 5.05¢ per kwh, the savings are adding up. In fact, they look better every day.

In January 1980 the cost per kwh was 3.73¢. "Who knows what it will be in another two years?" Wert asks.

But he had locked his water heating cost in at 1980 prices for lumber and copper tubing.

With more than two people using the hot water system the savings could be higher since more water would be circulated through the panels for warming and thus the savings could be realized over a larger amount of water than what Werts now are using.

Arthur Wert leaves no doubt he would install a solar system again on his farm if he had to do it all over. But he would make some changes.

"I think one of the secrets of speeding up grain drying is to use a grain cleaner to get the fines out of the crop. I'll have one this fall," he says, noting fines impede air flow through the corn.

In addition, he hopes to have a full crop this year to run through the system. Although it took 29 days to dry the corn with the half-full bin he figures it will take only 7 to 10 days more to dry a full 6,000 bushels.

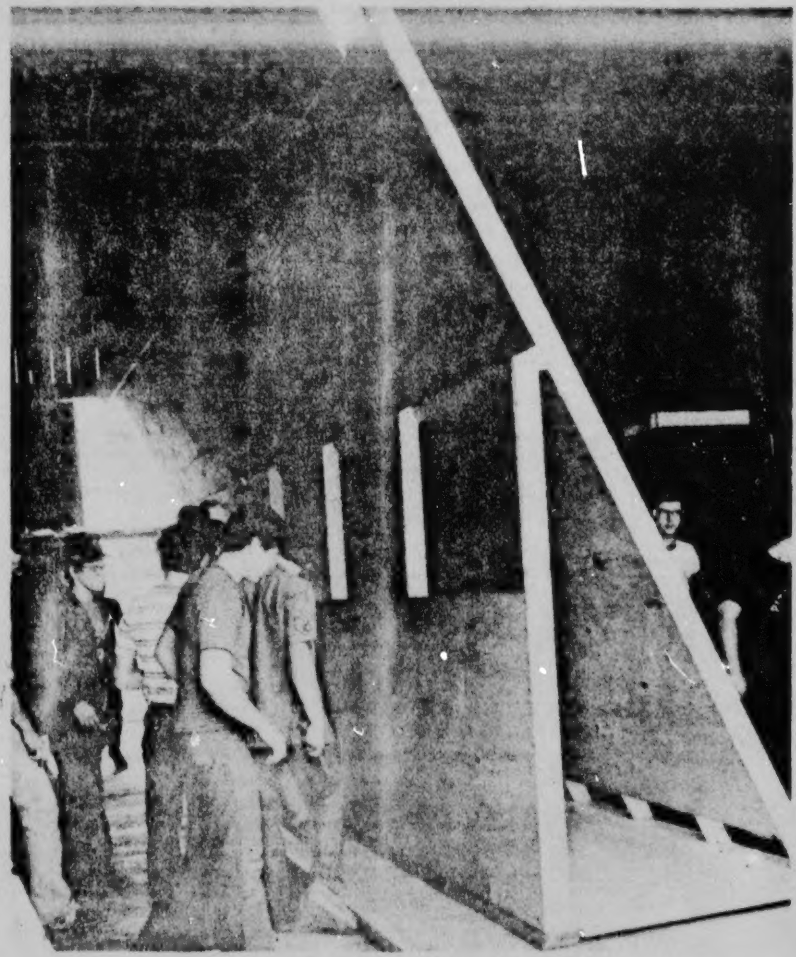
"The idea with in-bin drying is to keep the air flowing through the bin even on cloudy days," Arthur says. This maintains drying, though at a reduced rate. And with solar, even overcast days provide some solar energy.

A shirtless tractor operator often will get a bad sunburn on a cloudy day for the same reason — the body does not feel the heat as it would on a sunny day, but the solar energy is there and working.

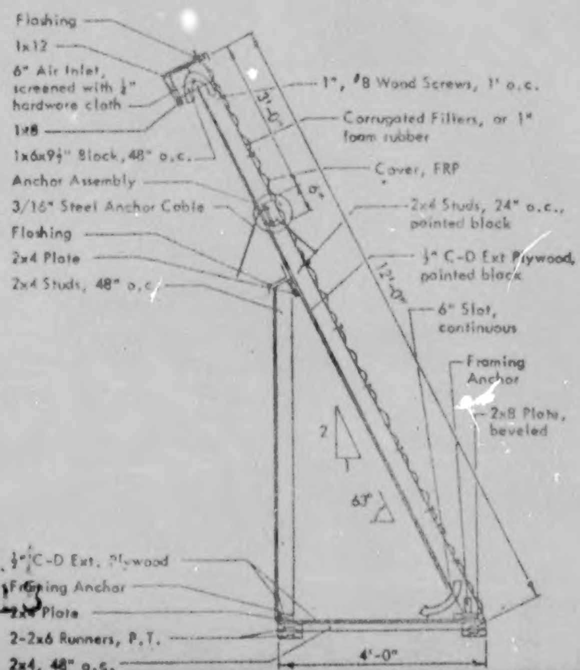
Wert put his panels on skids for easy moving. Two bolts on one end of the unit will take a chain which is attached by clevis to the tractor drawbar, and away the whole unit goes.

Wert had no problem with moldy grain at all. Slow in-bin drying provided him with a good, uncracked kernel and little extra shrink.

For Arthur Wert, the age of solar power has come. He already has locked his equipment and collector costs in to prices charged during the good old days of the fossil fuel era.



Last year this group of Mifflinburg FFA boys helped Arthur Wert construct his solar collector. Air is drawn in the lip at panel's top, and runs down the long, narrow space created by the 2x4 angling down and right, plywood backing, and solar panels out of sight around front. Air is drawn through the space at bottom, far right, into the large triangular area, shown uncompleted in photo. Air then is pulled out of triangular area by a fan which would be located in front of the larger group of workers, and thence to the grain bin. Diagram below matches this view.


Flashing
1x12
6" Air Inlet, screened with ½" hardware cloth
1x8
1x6x9½" Block, 48" o.c.
Anchor Assembly
3/16" Steel Anchor Cable
Flashing
2x4 Plate
2x4 Studs, 48" o.c.
1", #8 Wood Screws, 1' o.c.
Corrugated Fillers, or 1" foam rubber
Cover, FRP
2x4 Studs, 24" o.c., painted black
½" C-D Ext Plywood, painted black
6" Slot, continuous
Framing Anchor
2x8 Plate, beveled
3'-0"
12'-0"
2
1
63°
½" C-D Ext. Plywood
Framing Anchor
2x4 Plate
2-2x6 Runners, P.T.
2x4, 48" o.c.
4'-0"

STUDENT COMPETENCY SHEET

Module 7: Energy Conservation in Greenhouse Operations

Competency 1: Recognize sources of greenhouse heat loss

Introduction:

There are more than 7,500 acres of greenhouses in the USA. These greenhouses use the equivalent of about 300 million (that's 300,000,000) gallons of oil annually. Greenhouse operators claim that higher fuel prices may put them out of business. Yet, predictions call for still higher fuel prices.

Only two solutions exist for this dilemma: (1) intensify production of highly profitable greenhouse crops, and/or (2) reduce fuel consumption through energy efficiency measures.

In order to initiate energy conservation techniques, the greenhouse operator must be aware of various ways that heat is lost from greenhouse structures.

Resources and Equipment:

NRAES-3 (Bulletin), Energy Conservation & Solar Heating for Greenhouses

Learning Activities:

1. Read pp. 1-2 in the above reference (NRAES-3) and answer the following questions:
   - a. What are the three ways heat is lost from greenhouses? Give an example of each.
   - b. How does size and shape of the greenhouse influence heat loss?
   - c. How can selection of construction materials contribute to greenhouse energy efficiency?
2. Take a tour of your own greenhouse, the school's, or one in your community. Identify potential sources of heat loss and calculate (roughly) the surface area to ground area ratio of the structure.

Evaluation:

1. Turn in answers to questions in Learning Activity #1.
2. Turn in your list of potential heat loss sources identified in Learning Activity #2, and your calculations of surface to ground area ratio of the structure(s) visited.

STUDENT COMPETENCY SHEET

Module 7: Energy Conservation in Greenhouse Operations

Competency 2: Conserve energy through selection of insulating greenhouse coverings

Introduction:

When you go outdoors in winter time, what do you do to keep warm? Put on a jacket, longjohns, gloves, maybe overshoes? Sure. How do additional layers of clothing help keep you warm? Think back to the three ways heat is lost from greenhouses. Two of these apply to your own comfort as well.

In cold weather, layers of clothing trap air, thus insulating the body by preventing loss of heat (conduction). The layers of clothing also keep out the cold air (infiltration), so less body heat is needed.

The same principles apply to conserving energy in greenhouses. If we can make the covering air-tight, air infiltration can be prevented. And if we can trap air between layers of coverings, conduction losses can be greatly reduced.

Resources and Equipment:

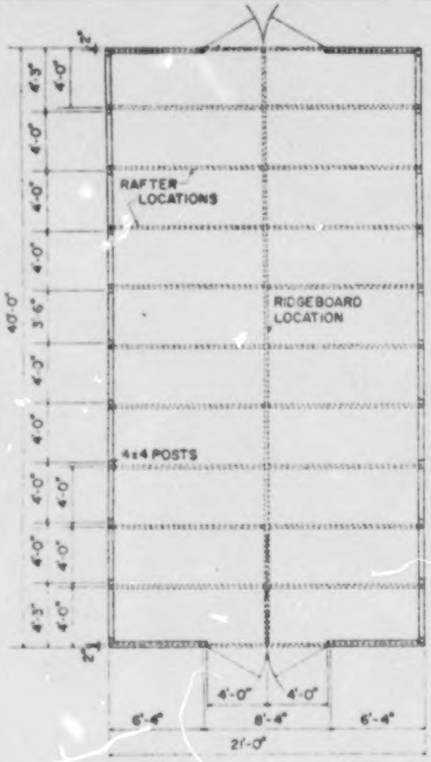
Bulletin NRAES-3, Energy Conservation & Solar Heating for Greenhouses

Learning Activities:

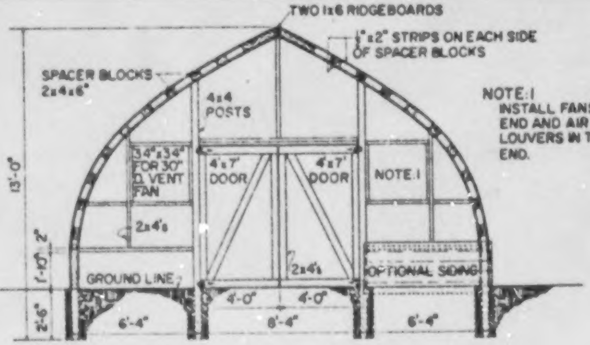
1. Read pp. 3-7 in the above reference (NRAES-3) and answer the following questions:
   a. What are three energy efficient methods of covering new or existing greenhouse structures?
   b. In using double polyethylene film coverings, what are two methods used to maintain space between the two layers?
   c. What are the cautions to observe in applying the double film technique over glass?
2. Examine the attached plans for small greenhouses. Evaluate each one with regard to its potential energy efficiency.

Evaluation:

1. Turn in answers to questions in Learning Activity #1.
2. Submit to your instructor your written evaluation of each greenhouse plan studied in Learning Activity #2.

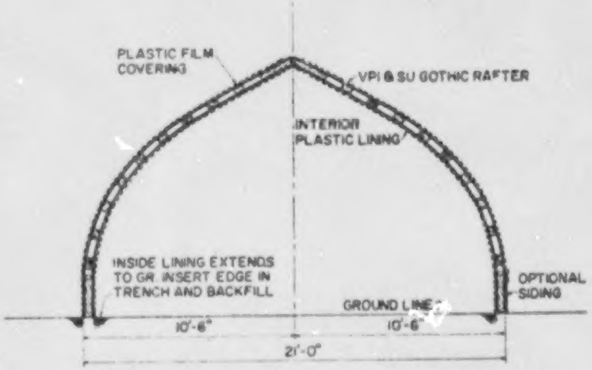

2"
4'-3"
4'-0"
4'-0"
4'-0"
4'-0"
3'-6"
4'-3"
4'-0"
4'-0"
4'-0"
4'-0"
4'-0"
4'-0"
4'-3"
4'-0"
40'-0"
2"
RAFTER LOCATIONS
RIDGEBOARD LOCATION
4x4 POSTS
4'-0"
4'-0"
6'-4"
8'-4"
6'-4"
21'-0"

FLOOR PLAN
SCALE 12" 0 1 2 3 4 6"

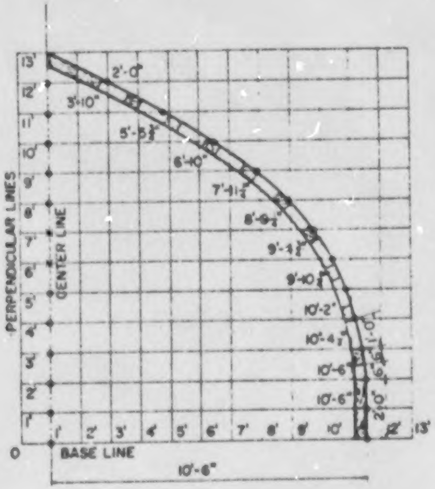

TWO 1x6 RIDGEBOARDS
½"x2" STRIPS ON EACH SIDE OF SPACER BLOCKS
SPACER BLOCKS 2x4x6"
4x4 POSTS
34"x34" FOR 30" D. VENT FAN
4'x7' DOOR
4'x7' DOOR
NOTE.1
2x4's
2x4's
OPTIONAL SIDING
GROUND LINE
13'-0"
2"
1'-10"
2'-6"
4'-0"
4'-0"
6'-4"
8'-4"
6'-4"

NOTE: 1
INSTALL FANS IN ONE END AND AIR INTAKE LOUVERS IN THE OTHER END.

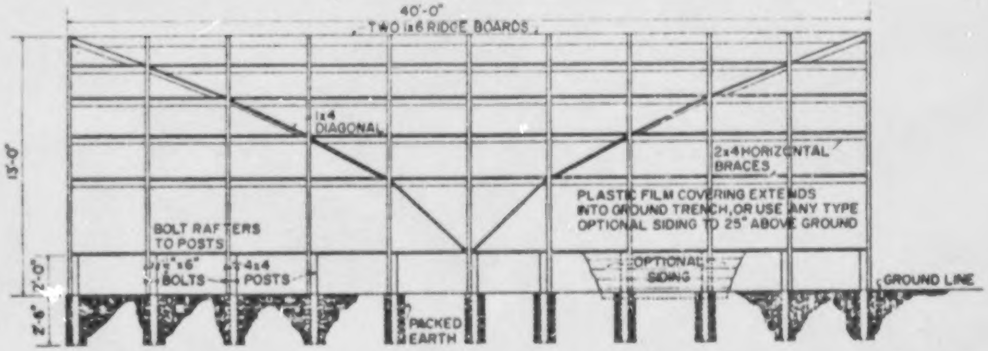
END VIEW OF FRAMING


PLASTIC FILM COVERING
VPI & SU GOTHIC RAFTER
INTERIOR PLASTIC LINING
INSIDE LINING EXTENDS TO GR. INSERT EDGE IN TRENCH AND BACKFILL
OPTIONAL SIDING
GROUND LINE
10'-6"
10'-6"
21'-0"

CROSS SECTION


PERPENDICULAR LINES
CENTER LINE
13'
12'
11'
10'
9'
8'
7'
6'
5'
4'
3'
2'
1'
0
1'
2'
3'
4'
5'
6'
7'
8'
9'
10'
12'
13'
2'-0"
3'-10"
5'-5¾"
6'-10"
7'-11½"
8'-9½"
9'-1½"
9'-10½"
10'-2"
10'-4½"
10'-6"
10'-6"
1'-0"
6'-6"
2'-0"
BASE LINE
10'-6"

VPI & SU GOTHIC RAFTER
SCALE: 12" 6" 0 1 2 3 4 9" 3"


40'-0"
TWO 1x6 RIDGE BOARDS
13'-0"
1x4 DIAGONAL
2x4 HORIZONTAL BRACES
PLASTIC FILM COVERING EXTENDS INTO GROUND TRENCH, OR USE ANY TYPE OPTIONAL SIDING TO 25" ABOVE GROUND
BOLT RAFTERS TO POSTS
½"x6" BOLTS
4x4 POSTS
OPTIONAL SIDING
GROUND LINE
PACKED EARTH
2'-0"
2'-6"

SIDE VIEW OF FRAMING

NOTE:
TREAT POST WITH PROPER PRESERVATIVE
DO NOT USE CREOSOTE OR PENTA TREATED POSTS

BASED ON: VIRGINA STATE
UNIVERSITY PLAN NO. N-2.11

12" 0 1 2 3 4
6"
SCALE UNLESS OTHERWISE NOTED

COOPERATIVE EXTENSION WORK IN
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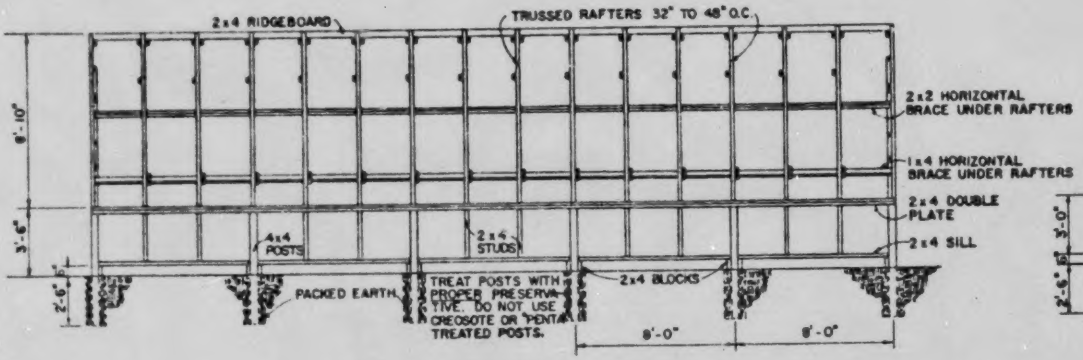
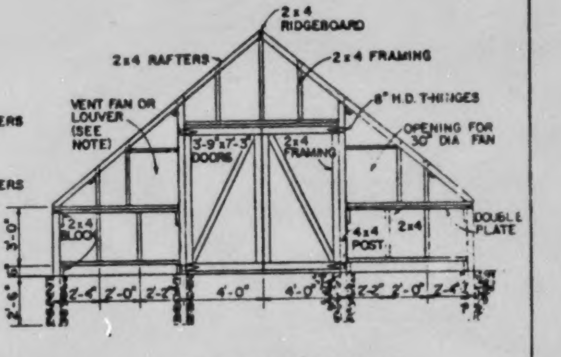
GOTHIC RAFTER GREENHOUSE

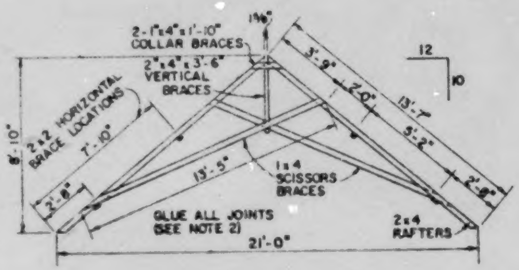
VA. '78	6298	SHEET 1 OF 1


2x4 RIDGEBOARD
TRUSSED RAFTERS 32" TO 48" O.C.
8'-10"
3'-6"
2'-6"
2x2 HORIZONTAL BRACE UNDER RAFTERS
1x4 HORIZONTAL BRACE UNDER RAFTERS
2x4 DOUBLE PLATE
2x4 SILL
4x4 POSTS
2x4 STUDS
PACKED EARTH
TREAT POSTS WITH PROPER PRESERVATIVE. DO NOT USE CREOSOTE OR "PENTA" TREATED POSTS.
2x4 BLOCKS
8'-0"
8'-0"

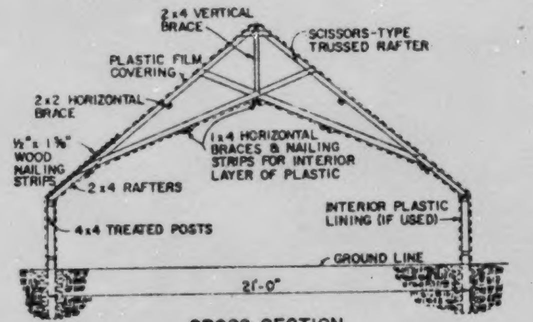
SIDE VIEW OF FRAMING


2x4 RIDGEBOARD
2x4 RAFTERS
2x4 FRAMING
8" H.D. T-HINGES
VENT FAN OR LOUVER (SEE NOTE)
3'-9"x7'-3" DOORS
2x4 FRAMING
OPENING FOR 30" DIA FAN
2x4 BLOCK
4x4 POST
2x4
DOUBLE PLATE
3'-0"
2'-6"
2'-2" 2'-0" 2'-2"
4'-0"
4'-0"
2'-2" 2'-0" 2'-2"

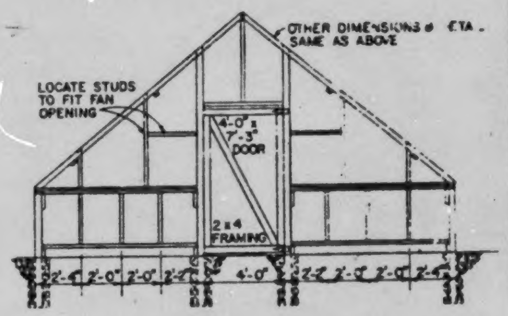
END VIEW OF FRAMING


2-1"x4"x1'-10" COLLAR BRACES
1⅝"
2"x4"x3'-6" VERTICAL BRACES
12
10
2x2 HORIZONTAL BRACE LOCATIONS
8'-10"
7'-10"
3'-9"
2'-0"
13'-7"
5'-2"
13'-5"
1x4 SCISSORS BRACES
2'-8"
2'-8"
GLUE ALL JOINTS (SEE NOTE 2)
2x4 RAFTERS
21'-0"

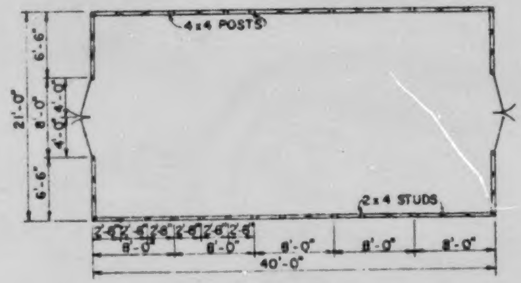
RAFTER DETAIL


2x4 VERTICAL BRACE
SCISSORS-TYPE TRUSSED RAFTER
PLASTIC FILM COVERING
2x2 HORIZONTAL BRACE
1x4 HORIZONTAL BRACES & NAILING STRIPS FOR INTERIOR LAYER OF PLASTIC
½"x 1⅝" WOOD NAILING STRIPS
2x4 RAFTERS
4x4 TREATED POSTS
INTERIOR PLASTIC LINING (IF USED)
GROUND LINE
21'-0"

CROSS SECTION


OTHER DIMENSIONS & ETC. SAME AS ABOVE
LOCATE STUDS TO FIT FAN OPENING
4'-0" x 7'-3" DOOR
2x4 FRAMING
2'-2" 2'-0" 2'-0" 2'-2"
4'-0"
2'-2" 2'-0" 2'-0" 2'-2"

ALTERNATE END VIEW


4x4 POSTS
21'-0"
6'-6"
8'-0"
4'-0"
4'-0"
6'-6"
2x4 STUDS
2'-6" 2'-6" 2'-6" 2'-6" 2'-6" 2'-6"
8'-0"
8'-0"
8'-0"
8'-0"
8'-0"
40'-0"

FLOOR PLAN

SCALE

NOTES

1. IF 30" FAN FRAMES ARE TOO LARGE FOR OPENING PROVIDED, LOWER PLATE AND MOVE STUD AS REQUIRED, OR USE THREE 24" FANS AND PLACE ONE IN GABLE OVER DOORS, OR MAKE DOORS NARROWER. (ALSO SEE ALTERNATE END VIEW OF FRAMING.)
2. ALL JOINTS GLUED (USE A GOOD WATERPROOF WOOD GLUE) AND NAILED WITH 6-PENNY, GALVANIZED SERRATED NAILS.
3. CONSULT LOCAL HEALTH AND BUILDING CODE AUTHORITIES BEFORE STARTING CONSTRUCTION.

UNLESS OTHERWISE NOTE

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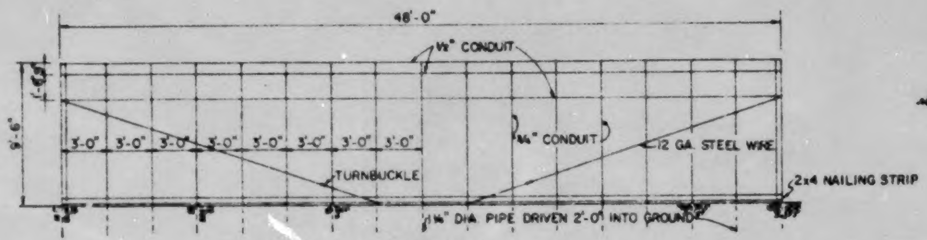
GREENHOUSE
SCISSORS TRUSS

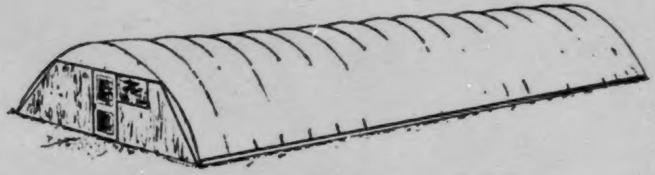
VA '78 | 6311 | SHEET 1 OF 1

BASED ON VA. POLYTECHNIC INST. PLAN NO. N-2.12


48'-0"
½" CONDUIT
¾" CONDUIT
12 GA. STEEL WIRE
TURNBUCKLE
2x4 NAILING STRIP
1¼" DIA. PIPE DRIVEN 2'-0" INTO GROUND
3'-0" 3'-0" 3'-0" 3'-0" 3'-0" 3'-0" 3'-0" 3'-0"
1'-3"
9'-6"

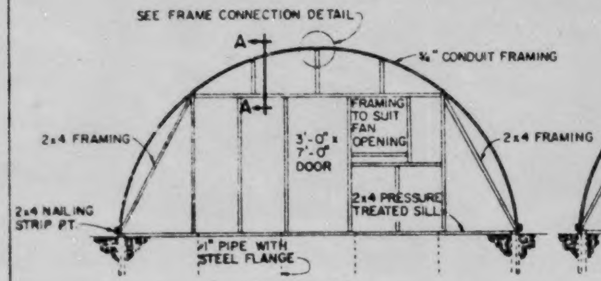
SIDE VIEW

SCALE

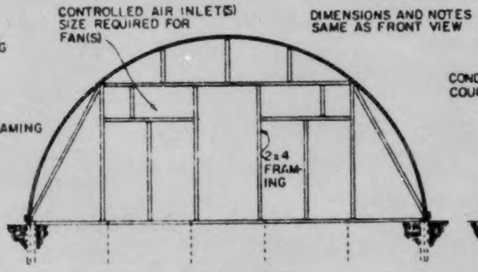


PERSPECTIVE

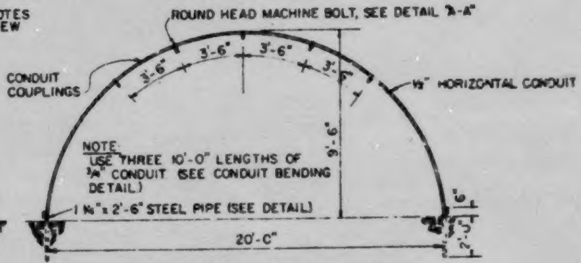
NOT TO SCALE


SEE FRAME CONNECTION DETAIL
A
A
¾" CONDUIT FRAMING
FRAMING TO SUIT FAN OPENING
3'-0" x 7'-0" DOOR
2x4 FRAMING
2x4 FRAMING
2x4 PRESSURE TREATED SILL
2x4 NAILING STRIP PT.
1" PIPE WITH STEEL FLANGE

FRONT VIEW

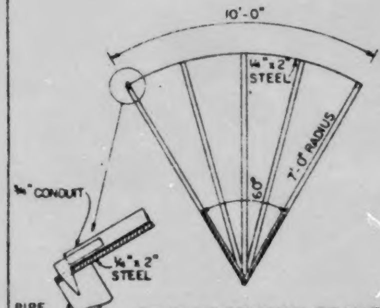

CONTROLLED AIR INLET(S) SIZE REQUIRED FOR FAN(S)
DIMENSIONS AND NOTES SAME AS FRONT VIEW
2x4 FRAMING

REAR VIEW


ROUND HEAD MACHINE BOLT, SEE DETAIL "A-A"
CONDUIT COUPLINGS
3'-6" 3'-6" 3'-6" 3'-6"
½" HORIZONTAL CONDUIT
NOTE: USE THREE 10'-0" LENGTHS OF ¾" CONDUIT (SEE CONDUIT BENDING DETAIL)
9'-6"
1¼" x 2'-6" STEEL PIPE (SEE DETAIL)
20'-0"
6"
2'

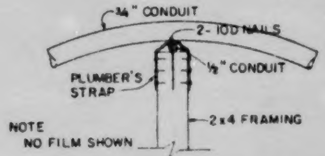
TYPICAL CONDUIT FRAME

SCALE


10'-0"
¼" x 2" STEEL
7'-0" RADIUS
60°
¾" CONDUIT
¼" x 2" STEEL
PIPE SUPPORT

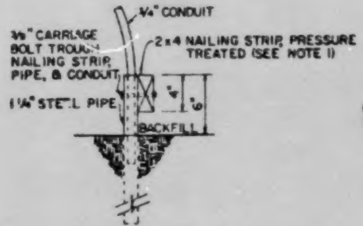
CONDUIT BENDING FRAME

NOT TO SCALE


¾" CONDUIT
2- 10D NAILS
½" CONDUIT
PLUMBER'S STRAP
2x4 FRAMING
NOTE NO FILM SHOWN

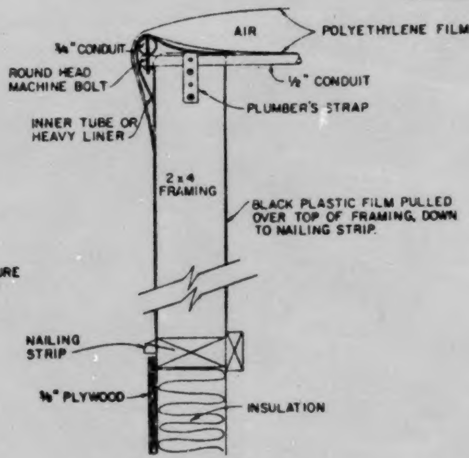
FRAME CONNECTION DETAIL

SCALE 3" = 1'-0"


¾" CONDUIT
⅜" CARRIAGE BOLT THROUGH NAILING STRIP, PIPE, & CONDUIT
2x4 NAILING STRIP, PRESSURE TREATED (SEE NOTE 1)
1¼" STEEL PIPE
BACKFILL
4"
6"

PIPE DETAIL

SCALE


AIR
POLYETHYLENE FILM
¾" CONDUIT
½" CONDUIT
ROUND HEAD MACHINE BOLT
PLUMBER'S STRAP
INNER TUBE OR HEAVY LINER
2x4 FRAMING
BLACK PLASTIC FILM PULLED OVER TOP OF FRAMING, DOWN TO NAILING STRIP.
NAILING STRIP
⅜" PLYWOOD
INSULATION

DETAIL "A-A"

NOTES:

1) DO NOT USE CREOSOTE OR "PENTA" TREATED WOOD
2) CONSULT LOCAL HEALTH AND BUILDING CODE AUTHORITIES BEFORE STARTING CONSTRUCTION
3) ROLL JIGS OR OTHER ARRANGEMENTS FOR BENDING CONDUIT CAN BE USED

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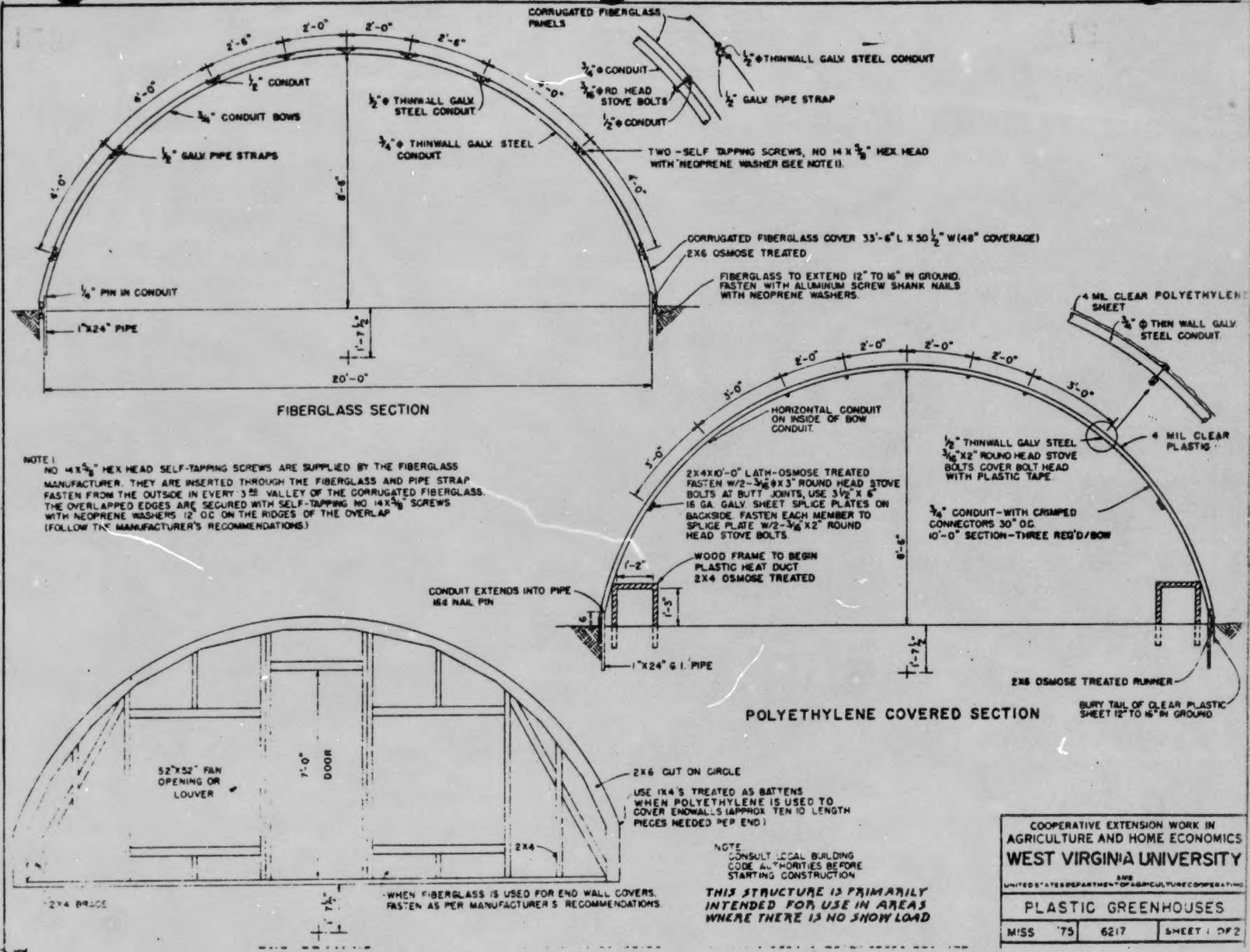
GREENHOUSE
PIPE FRAME

VA. '78	6312	SHEET 1 OF 1


CORRUGATED FIBERGLASS PANELS
½" ⌀ THINWALL GALV. STEEL CONDUIT
¾" ⌀ CONDUIT
³⁄₁₆" ⌀ RD HEAD STOVE BOLTS
½" ⌀ CONDUIT
½" GALV. PIPE STRAP
2'-0"
2'-0"
2'-6"
2'-6"
6'-0"
6'-0"
6'-0"
6'-0"
½" CONDUIT
¾" CONDUIT BOWS
½" GALV. PIPE STRAPS
½" ⌀ THINWALL GALV. STEEL CONDUIT
¾" ⌀ THINWALL GALV. STEEL CONDUIT
TWO - SELF TAPPING SCREWS, NO 14 X ⅝" HEX HEAD WITH NEOPRENE WASHER (SEE NOTE 1).
8'-6"
CORRUGATED FIBERGLASS COVER 33'-6" L X 50½" W (48" COVERAGE)
2X6 OSMOSE TREATED
FIBERGLASS TO EXTEND 12" TO 16" IN GROUND. FASTEN WITH ALUMINUM SCREW SHANK NAILS WITH NEOPRENE WASHERS.
⅛" PIN IN CONDUIT
1"X24" PIPE
1'-7½"
20'-0"
4 MIL CLEAR POLYETHYLENE SHEET
¾" ⌀ THIN WALL GALV. STEEL CONDUIT
2'-0"
2'-0"
2'-0"
2'-0"
3'-0"
3'-0"
3'-0"
HORIZONTAL CONDUIT ON INSIDE OF BOW CONDUIT.
½" THINWALL GALV STEEL ³⁄₁₆"X2" ROUND HEAD STOVE BOLTS COVER BOLT HEAD WITH PLASTIC TAPE.
4 MIL CLEAR PLASTIC
2X4X10'-0" LATH-OSMOSE TREATED FASTEN W/2-³⁄₁₆" ⌀ X 3" ROUND HEAD STOVE BOLTS AT BUTT JOINTS, USE 3½" X 6" 16 GA. GALV. SHEET SPLICE PLATES ON BACKSIDE. FASTEN EACH MEMBER TO SPLICE PLATE W/2-³⁄₁₆" X 2" ROUND HEAD STOVE BOLTS.
¾" CONDUIT-WITH CRIMPED CONNECTORS 30" O.C. 10'-0" SECTION-THREE REQ'D/BOW
8'-6"
1'-2"
WOOD FRAME TO BEGIN PLASTIC HEAT DUCT 2X4 OSMOSE TREATED
CONDUIT EXTENDS INTO PIPE 16d NAIL PIN
6
1'-5"
1"X24" G.I. PIPE
1'-7½"
2X6 OSMOSE TREATED RUNNER
BURY TAIL OF CLEAR PLASTIC SHEET 12" TO 16" IN GROUND
52"X52" FAN OPENING OR LOUVER
7'-0"
DOOR
2X6 CUT ON CIRCLE
USE 1X4'S TREATED AS BATTENS WHEN POLYETHYLENE IS USED TO COVER ENDWALLS (APPROX TEN 10 LENGTH PIECES NEEDED PER END)
2X4
2X4 BRACE
WHEN FIBERGLASS IS USED FOR END WALL COVERS, FASTEN AS PER MANUFACTURER'S RECOMMENDATIONS.

FIBERGLASS SECTION

NOTE 1
NO 14X⅝" HEX HEAD SELF-TAPPING SCREWS ARE SUPPLIED BY THE FIBERGLASS MANUFACTURER. THEY ARE INSERTED THROUGH THE FIBERGLASS AND PIPE STRAP. FASTEN FROM THE OUTSIDE IN EVERY 3RD VALLEY OF THE CORRUGATED FIBERGLASS. THE OVERLAPPED EDGES ARE SECURED WITH SELF-TAPPING NO 14X⅝" SCREWS WITH NEOPRENE WASHERS 12" O.C. ON THE RIDGES OF THE OVERLAP (FOLLOW THE MANUFACTURER'S RECOMMENDATIONS.)

POLYETHYLENE COVERED SECTION

NOTE
CONSULT LOCAL BUILDING CODE AUTHORITIES BEFORE STARTING CONSTRUCTION

THIS STRUCTURE IS PRIMARILY INTENDED FOR USE IN AREAS WHERE THERE IS NO SNOW LOAD

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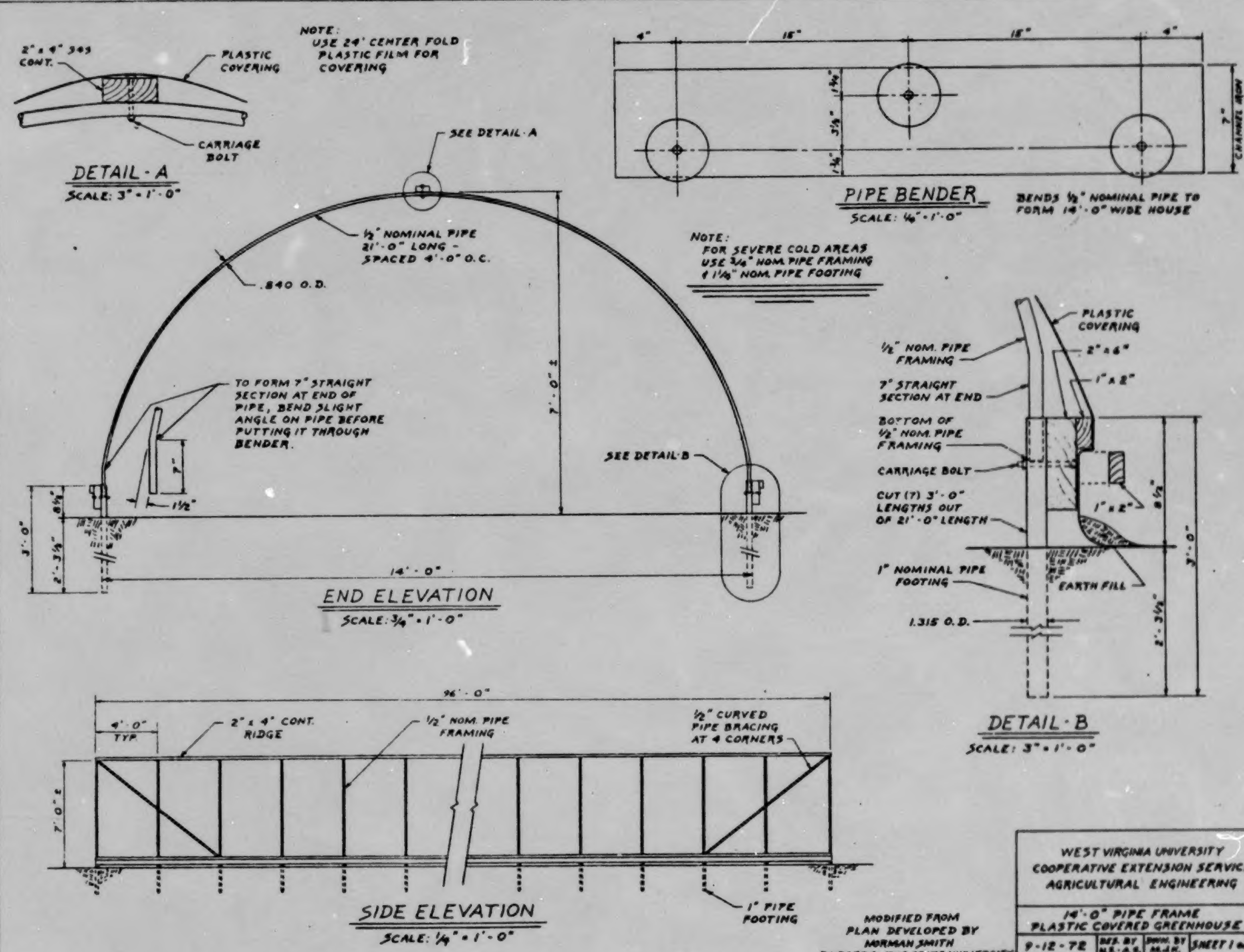
PLASTIC GREENHOUSES

MISS '75	6217	SHEET 1 OF 2


2" x 4" S4S
CONT.
PLASTIC
COVERING
CARRIAGE
BOLT
DETAIL - A
SCALE: 3" = 1' - 0"
NOTE:
USE 24' CENTER FOLD
PLASTIC FILM FOR
COVERING
SEE DETAIL - A
½" NOMINAL PIPE
21' - 0" LONG -
SPACED 4' - 0" O.C.
.840 O.D.
TO FORM 7" STRAIGHT
SECTION AT END OF
PIPE, BEND SLIGHT
ANGLE ON PIPE BEFORE
PUTTING IT THROUGH
BENDER.
7"
1½"
8½"
3' - 0"
2' - 3½"
7' - 0" ±
SEE DETAIL - B
14' - 0"
END ELEVATION
SCALE: ¾" = 1' - 0"
4"
15"
15"
4"
1¾"
3½"
1¾"
7" CHANNEL IRON
PIPE BENDER
SCALE: ⅛" = 1' - 0"
BENDS ½" NOMINAL PIPE TO
FORM 14' - 0" WIDE HOUSE
NOTE:
FOR SEVERE COLD AREAS
USE ¾" NOM. PIPE FRAMING
& 1¼" NOM. PIPE FOOTING
PLASTIC
COVERING
½" NOM. PIPE
FRAMING
2" x 6"
1" x 2"
7" STRAIGHT
SECTION AT END
BOTTOM OF
½" NOM. PIPE
FRAMING
CARRIAGE BOLT
CUT (7) 3' - 0"
LENGTHS OUT
OF 21' - 0" LENGTH
1" x 2"
8½"
3' - 0"
1" NOMINAL PIPE
FOOTING
EARTH FILL
1.315 O.D.
2' - 3½"
DETAIL - B
SCALE: 3" = 1' - 0"
96' - 0"
4' - 0"
TYP.
2" x 4" CONT.
RIDGE
½" NOM. PIPE
FRAMING
½" CURVED
PIPE BRACING
AT 4 CORNERS
7' 0" ±
1" PIPE
FOOTING
SIDE ELEVATION
SCALE: ¼" = 1' - 0"

MODIFIED FROM
PLAN DEVELOPED BY
NORMAN SMITH
RUTGERS - THE STATE UNIVERSITY
DWG. 153 N.J. 69

WEST VIRGINIA UNIVERSITY
COOPERATIVE EXTENSION SERVICE
AGRICULTURAL ENGINEERING

14' - 0" PIPE FRAME
PLASTIC COVERED GREENHOUSE

9-12-72	DES. BY N.S.-A.S.	DWN. BY M.J.H.	SHEET 1 of 1
MI - 138			

STUDENT COMPETENCY SHEET

Module 7: Energy Conservation in Greenhouse Operations

Competency 3: Conserve energy with movable interior blankets

Introduction:

Greenhouses depend on sunshine to help create a climate conducive for plant growth. Among other plant needs, light and temperature requirements are critical. During winter, sunshine warms the air inside a greenhouse. Solar heat also warms and is stored in concrete, plants, soil and other objects in the structure. At night, this heat readily escapes through greenhouse coverings. Necessity for supplemental heating can be reduced considerably if the solar heat can be trapped inside the greenhouse.

Resources and Equipment:

Bulletin NRAES-3, Energy Conservation & Solar Heating for Greenhouses

Learning Activities:

1. Read pp. 8-14 in the above reference (NRAES-3) and answer the following questions:
    a. At $1.00 per gallon fuel oil, what is the cost of heat for a 14,000 square foot greenhouse of:
        1) lapped glass?
        2) lapped glass with interior blankets?
        3) lapped glass with inflated plastic film plus interior blankets?

        (Table 1, page 8)
    b. Of what materials can interior blankets be made? Which might be most economical?
    c. How can interior blankets be suspended? stored?
2. Examine your own greenhouse, the school's, or one in your community. Design a plan for installing interior blankets to reduce nighttime heat losses. Include materials, methods and costs.

Evaluation:

1. Turn in answers to questions in Learning Activity #1.
2. Submit to your teacher your plan for installation of interior blankets in a greenhouse (Learning Activity #2) for grading.

STUDENT COMPETENCY SHEET

Module 7: Energy Conservation in Greenhouse Operations

Competency 4: Conserve energy through greenhouse management techniques

Introduction:

A farmer at an adult class one evening made the statement, "If I only farmed as well as I already know how, I could probably double my income." The same situation undoubtedly exists in most greenhouses. There are lots of little things we already know how to do to conserve energy (and increase income), but somehow we just never seem to get around to doing them.

Resources and Equipment:

Bulletin NRAES-3, Energy Conservation & Solar Heating for Greenhouses

Learning Activities:

1. Some of the "little" things that can plug the leaks in your energy barrel are discussed in NRAES-3 on pages 15-19. After reading these pages, make a list of items to be checked in any greenhouse. Your checklist may begin something like this:

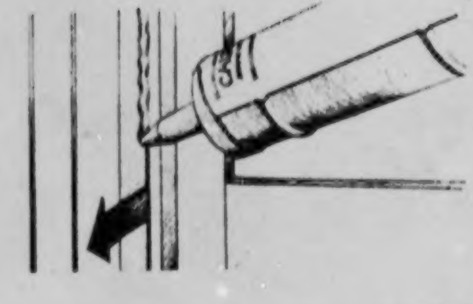
	Satisfactory	Needs Attention
a. Reduce air leaks		
1) Gaps and holes in coverings	( )	( )
2) Broken glass	( )	( )
3) Weatherstripping on doors	( )	( )
4) Weatherstripping on windows	( )	( )
5) Ventilation louvers operate freely	( )	( )
6) Calking between foundation and plate	( )	( )

Prepare a complete checklist for potential greenhouse heat losses. Add to those items mentioned in your reference if you can.

2. Using your checklist, examine your own greenhouse, the school's or one in your community, and locate existing problems.

Evaluation:

Turn in your checklist on which you have identified existing problems in the greenhouse examined.



ENERGY CONSERVATION & SOLAR HEATING FOR GREENHOUSES

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Trade names have been used in this publication to simplify information. No endorsement of named products is intended; nor is criticism implied of similar products which are not mentioned.

NRAES-3
$1.50

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ENERGY CONSERVATION

With intense use of energy, greenhouse growers produce yields that are five to fifteen times greater than field yields. Many ideas have been proposed to help reduce the high costs associated with heating greenhouses. Both research and grower experience have shown that it is possible to reduce fuel use substantially. Methods range from ordinary maintenance of structures and heating units to structural or cover changes.

This manual discusses the merits and limitations of most of the energy conserving ideas and systems available today. In addition, some installation pointers and a section on analyzing the economic benefits of energy conservation measures are included.

The fact remains, however, that the greenhouse is not designed to save energy, but to produce a profitable crop under controlled conditions. Efforts to save energy which limit the production of crops or cause a change in schedule so that a market is missed may be energy conserving, but they are not always economical. Thus it is important to analyze carefully any energy conservation measure before it is applied to the greenhouse.

Principles of Heat Loss

Conduction, Infiltration and Radiation

Heat is lost from a greenhouse in three ways. The largest heat loss is usually by conduction through the covering material on walls and roof.

The second form of heat loss is by air infiltration through holes or cracks. The amount of air infiltration depends on the tightness of the construction and the type of cover used.

Infrared or thermal radiation, generated by warm substances, is a third form of heat loss. Plants receive solar radiation and transmit thermal radiation to the sky. Thermal (long wave) radiation passes through polyethylene (80 percent transmission) much faster than glass (3 percent transmission) or corrugated fiberglass (8 percent transmission). For this reason, polyethylene houses sometimes cool more rapidly at night than glass or fiberglass houses. Often, though, moisture condenses on polyethylene coverings; so they generally lose little or no more heat than glass or fiberglass covered houses.

Size and Shape

Small greenhouses have a large surface area to volume ratio. For this reason they are harder to heat and require more heat per square foot of floor area than large houses. Air far from the greenhouse surface is less affected by surface cooling so small surface area to volume ratios are desired.

Small greenhouses also have large surface area to ground area ratios of 4 to 1 or more. Large ridge and furrow greenhouses approach the smallest ratio of about 1.2 to 1. Keeping the outside exposed surface area to a minimum reduces the heat loss.

Construction Materials

Construction materials also affect heat loss. Polyethylene reduces air infiltration because it is a tighter continuous cover than panes of glass. As a glass greenhouse gets older, the glass loosens, and permits more air infiltration. Two layers of any material separated by an air space reduces heat transmission.

Steel or aluminum frames lose more heat by conduction than wood frames. Plastic is sometimes used to cover aluminum or steel frames to reduce this conduction loss.

Insulating Techniques

Several insulating techniques hold promise for reduced energy consumption. Movable blankets or thermal screens, polyethylene either in single or double layers over glass and fixed polyethylene liners within glass houses are being used.

Double Polyethylene Film

Double polyethylene covered greenhouses are inherently energy conservative. The measured overall heat loss, called the U factor, for some designs is 0.7 BTU per hour per square foot of surface per °F temperature difference. In comparison, the U factor is 1.15-1.2 for single glazed structures of other materials; or a double polyethylene covered greenhouse can save at least 30 percent for heating.

The installation cost for the heating equipment in a double poly covered house will also be proportionally less. In fact an oversize heating unit should be avoided. Even though large heating units run less often, they are less efficient than smaller ones that run for longer periods of time. In one test a heater, burning on short cycles for a total of 4 hours per day was only 63% efficient. When the same heater burned almost continuously for 20 hours per day, its efficiency increased to better than 80%.

Double-layer polyethylene covered wood-frame houses are popular in some areas. The layers may be mechanically separated by 2 × 2 wood strips or inflated by a blower.

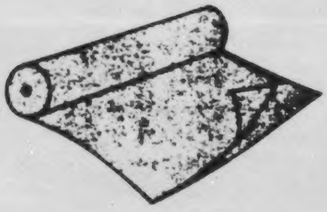
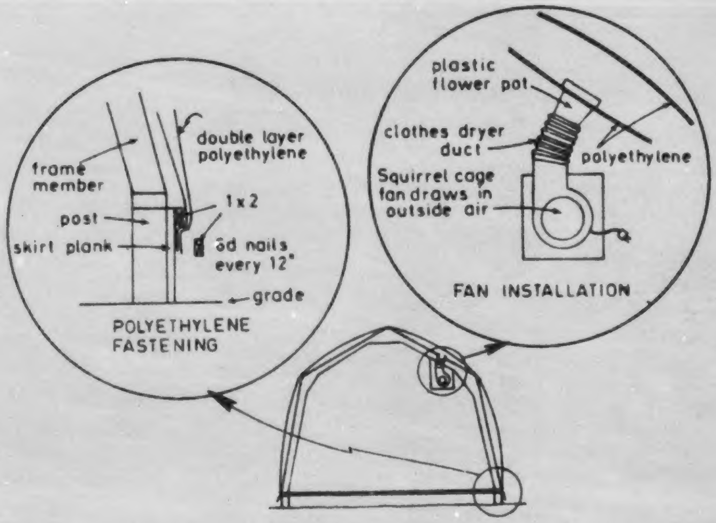


Figure 1: Details of an Air Inflated Polyethylene Covered Greenhouse

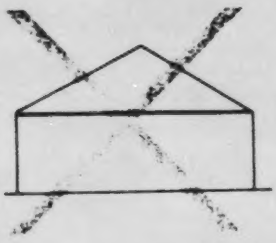

plastic flower pot
clothes dryer duct
polyethylene
Squirrel cage fan draws in outside air
FAN INSTALLATION
double layer polyethylene
frame member
1x2
post
skirt plank
3d nails every 12"
grade
POLYETHYLENE FASTENING

Double Wall Acrylic Panels

Several new double wall plastic glazing panels are available. The U factor for these double wall panels range from 0.55 to 0.70. The light transmission of the panels range from 75 to 85% of the available light. A double wall acrylic panel has been used commercially in Europe and Penn State University studies indicate it may be a viable option for energy conservation applications.

Some caution should be observed before using these panels. Their better insulation value may require that heavier greenhouse frames be used in areas with heavy snow. In addition, they may cost more than a conventional house with an internal blanket system.

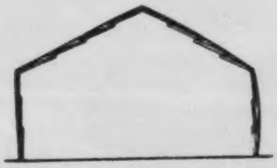
Fixed Interior Curtains



Fixed horizontal curtains inside the greenhouse are **NOT** recommended in the Northeast. Horizontal surfaces reflect light back out of the greenhouse during winter months when light is critical. More seriously, if the roof is insulated, during a heavy snowstorm the building may collapse. For this reason an interior curtain may void any insurance on the building.

Exterior polyethylene liners or covers and movable interior curtains are much safer options for reducing heat loss. A movable curtain can be opened or the exterior cover with air separation can be deflated to permit enough heat loss to melt the accumulating snow.

Liners



A lining of polyethylene film placed along the outside covering of the greenhouse can substantially reduce heat loss. Work in England in a glass house indicated a savings of 30 percent but with a light reduction of 14 percent and a yield reduction during the winter. In New York, one study showed a 50% heat savings in a glass house.

The effect of the plastic covering on the greenhouse is dependent upon how tight the house is. Infiltration, particularly on windy nights, is greatly reduced by the plastic film. In New Jersey, growers using fiberglass greenhouses are reporting a savings of 30 percent with an inflated layer of polyethylene film over the fiberglass covering.

Air Inflated Covers for Glass Greenhouses

The use of a double covering of air inflated plastic over glass is becoming widespread. Ohio State University has reported energy savings of 57%, and, although yields of some crops are less, the net effect is a savings of dollars to the grower.

The Ohio study measured a solar radiation reduction of 35 percent within a conventional glass greenhouse. After the double plastic was installed, an additional 18 percent light reduction was measured. The plastic cover tended to diffuse the light more uniformly within the greenhouse and structural shading was less apparent.

In the same study, daytime relative humidity during winter months when vents were closed was measured about 12 percent greater in the plastic covered greenhouse than in the conventional glass house.

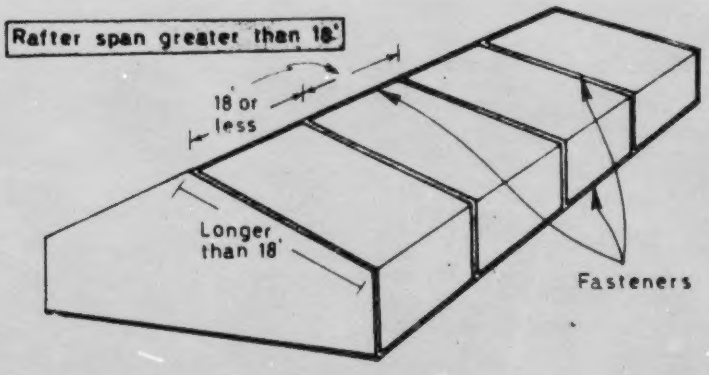
Maximum Span

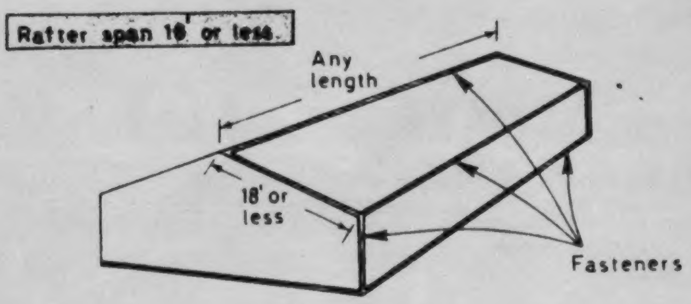
Some caution should be observed in applying the double film technique over glass. The internal stress in the film increases directly as the pressure increases and as the square of the span length. A 20 foot span has 4 times the internal film stress of a 10 foot span.

Eighteen feet is the maximum recommended span in one direction for an air inflated covering; so the rafter length should be about 18 feet. In this case, the film may be any length.

For greenhouses with longer rafter lengths, the film should be attached to the greenhouse with hold-down strips every 18 feet. If 20 feet diameter polyethylene tubing is used, the film can be run up and down the rafter and fastened at the 18 ft mark or at a main member of the greenhouse framing. A simple manifold of 3 inch PVC pipe can be made to join the side by side sections together.

Figure 2: Fastening Dimensions for Air Inflated Double Polyethylene Liners

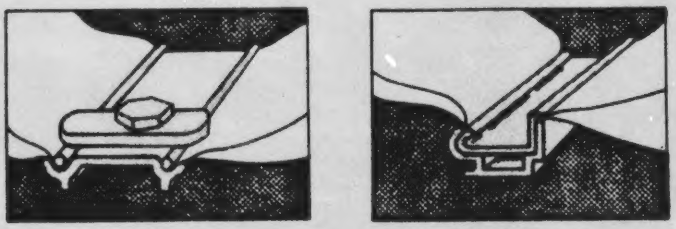




Equipment and Materials

Cover with an ultraviolet light (UV) resistant plastic film manufactured for greenhouse use. Use at least a 4 mil thick sheet for the inner layer and a 6 mil outer sheet.

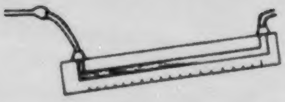
Fastening devices, such as those illustrated, are available from most plastic greenhouse manufacturers.



Fastening Devices

Inflate with a small blower capable of delivering 100 to 150 cubic feet per minute (cfm) at free air delivery. Before purchasing, check that the blower does not deliver air at more than a static pressure of 0.5 inch of water. Higher pressures will damage the plastic, the connectors, the greenhouse or all three. Mount the blower near the eaves so that outside air can be drawn into the blower to reduce condensation between the film layers.

Build a damper for the blower intake to regulate the air pressure in the system. Duct the blower to the plastic film envelope with 4 inch flexible tubing or a clothes dryer duct and duct tape. If the pressure is still too high, cut a few holes in the duct leading to the envelope to regulate the pressure.



Inclined manometer

A good covering job will result in few leaks, so the blower should operate with the damper closed. If many leaks are present, or there are tears in the plastic, more air will have to be delivered. The fan size may be increased in volume, not pressure; or fewer sections should be connected together with plastic ducts.

Dial Manometer

Purchase an inclined manometer or dial gauge to measure pressure between the plastic layers. Adjust the damper or holes to achieve a static pressure of 0.25 inch of water.

Installation of Air Inflated Cover for Glass Greenhouses

Step 1. Remove all sharp protruding objects from the outside surface of the greenhouse to prevent puncturing or tearing of plastic during application.

Step 2. Obtain aluminum or plastic securing devices to achieve uniform and secure fastening. It is very important that the securing devices be firmly fastened to the greenhouse. Bolting through the frame, particularly a wooden frame, is most reliable.

Step 3. Repair weak sash bars or attach the plastic securing device to the gutter. Sash bars must be firmly attached to the gutter plate before securing devices are fastened to them.

Step 4. Attach plastic securing devices to the bottom of the sash bars just below the vents if the vents are used.

Step 5. Wash outside glass with glass cleaning compound or water and brush to insure better light transmission through glass.

Step 6. If top vents are not being used and the total length of the roof from gutter to gutter is less than 40 ft, attach securing devices at the gutters and cover the entire greenhouse with two single sheets of plastic.

Step 7. If the greenhouse is longer than available plastic, a transition fastener can be located at one end of the sash bars. These same fasteners are often used at the end of the roof.

Step 8. On a calm day, roll out the plastic over the greenhouse superstructure. A portable scaffold is very helpful for this job.

Step 9. Fasten the plastic film with the securing devices. Avoid excessive pulling and stretching of the plastic before and during securing since all wrinkles will disappear after inflation. Straps or tiedowns across the top of the plastic sheets are not recommended since they are more likely to tear the plastic than hold it in place.

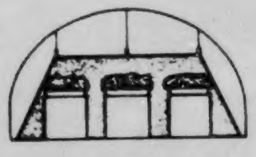
Step 10. Once both sheets of plastic are secured, attach the blower duct to the bottom layer of plastic.

Step 11. Begin inflating. Insert a pressure gauge when the plastic is inflated. Adjust the damper intake to maintain a pressure of 0.25".

Movable Interior Blankets

Movable screens or blankets are gaining acceptance in the U.S. and Europe. The internal blanket system consists of a flexible material, such as polyethylene film constructed and supported so that it will completely enclose the crop zone during the night. It must be movable so it can be stored during the day and cast a minimum shadow on the crop. The support for the blanket can be track, cable, wire, or combinations of them.

Blankets completely enclose the crop zone during the night



Heat Savings

Work at Rutgers, Pennsylvania State and Cornell Universities, in glass houses using polyethylene black cloth shading systems, indicated heat savings of nearly 60 percent (Table 1). The systems are so effective that almost all materials can be paid for rapidly.

Table 1: Annual Fuel Requirements for a 14,000 sq ft (1300 sq meters) Glass Greenhouse in Central Pennsylvania for an average year.

Fuel Conservation Technique	Fuel Use	
	Gallons of Oil	% of Annual Demand
Base – lapped glass gable shape	30,345	100
Base + single film plastic on walls	27,000	89
Base + single film plastic on south wall + insulation R=8 on north wall	25,790	85
Base + single film plastic on walls + interior thin blankets	16,990	56
Base + interior thin blankets	20,330	67
Base + double inflated plastic film over entire surface	16,080	53
Base + double inflated plastic film over entire surface & interior thin blankets	10,920	36

From a report submitted by C.A. Rotz, PSU 1977.

Energy savings in double covered polyethylene houses are less dramatic because the heat loss without blankets is approximately 33 percent less than a comparable glass house. A small double covered polyethylene film greenhouse equipped with a movable black polyethylene blanket has an average U value of 0.45 to 0.5 Btu/hour sq ft °F compared to a design value of 0.7 for a house with no curtain.

Typical Blanket Systems

Several systems move either across the short dimension of the greenhouse or along the long dimension.

Clear Span—Freestanding Greenhouse

Figure 3 illustrates a system used in clear span freestanding greenhouses where crops are not supported from the trusswork. Individual small pulleys support the blanketing material on powered cables which are spaced 10-12 feet apart. Static lines between the drive cables also support the curtain. The curtain is normally stored in the north wall. In wide houses, over 40 feet, the curtain is drawn from each side toward the middle.

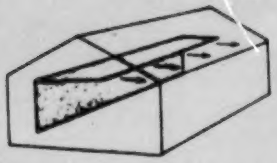
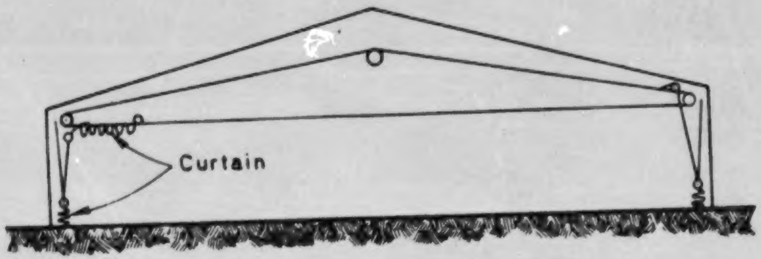


Figure 3: Curtain System for Clear Span Greenhouses with no crop hanging from the superstructure.

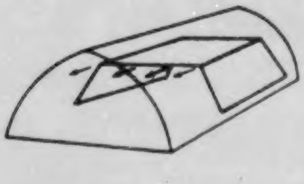


European

European systems, in the classic Dutch house, utilize curtains which move above the framework used for supporting the crop. The curtain moves from one gutter to the next in gutter connected (ridge and-furrow) houses (Figure 4). The leading edge of the curtain is pulled by a pipe drawn by cables spaced approximately 10 feet apart. The blanketing material is supported by monofilament plastic line approximately 24 inches on center. Some systems use monofilament plastic lines over the blanket to help keep the blanket in place when the mechanism withdraws the blanket. This system is commonly used in Europe for 25-40% shading with a porous translucent material.

Figure 5: Aluminum Track System for Curved Roof Greenhouses.

Curtain moves along the long dimension of the greenhouse.



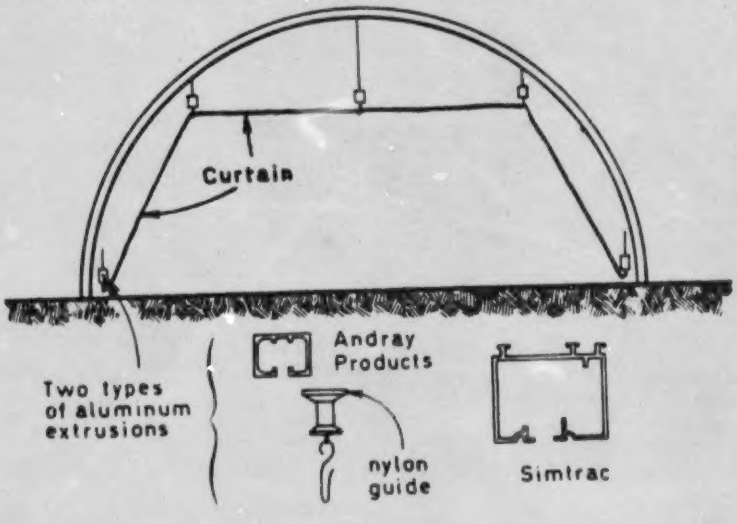
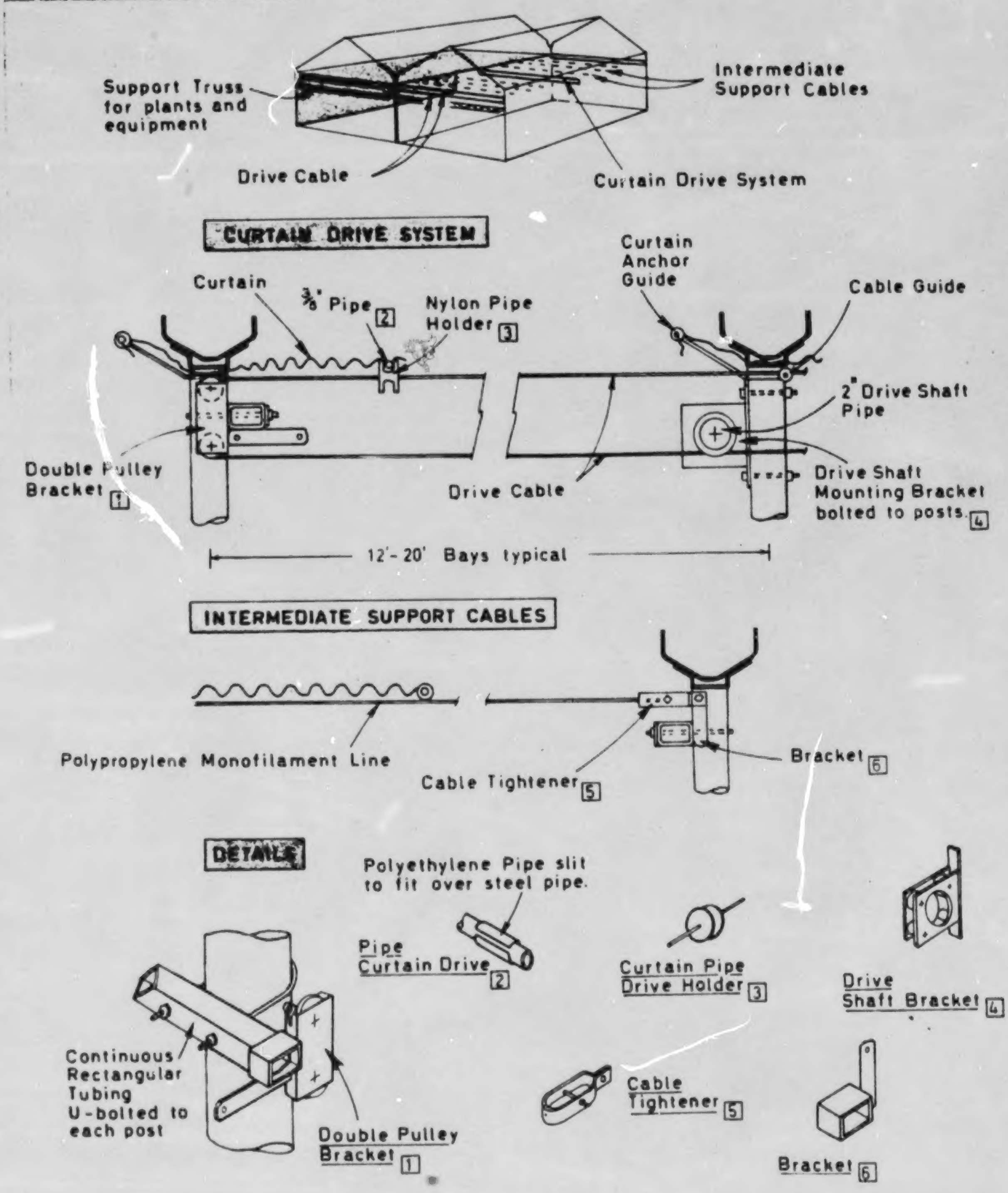


Figure 4: Curtain System for Gutter Connected Greenhouses.


Support Truss for plants and equipment
Intermediate Support Cables
Drive Cable
Curtain Drive System
CURTAIN DRIVE SYSTEM
Curtain
3/8" Pipe 2
Nylon Pipe Holder 3
Curtain Anchor Guide
Cable Guide
2" Drive Shaft Pipe
Double Pulley Bracket 1
Drive Cable
Drive Shaft Mounting Bracket bolted to posts. 4
12'-20' Bays typical
INTERMEDIATE SUPPORT CABLES
Polypropylene Monofilament Line
Cable Tightener 5
Bracket 6
DETAILS
Polyethylene Pipe slit to fit over steel pipe.
Pipe Curtain Drive 2
Curtain Pipe Drive Holder 3
Drive Shaft Bracket 4
Continuous Rectangular Tubing U-bolted to each post
Double Pulley Bracket 1
Cable Tightener 5
Bracket 6

Curved Walls

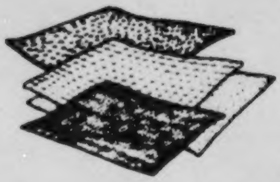
In some greenhouses—in particular curved rafter polyethylene or fiberglass covered greenhouses—horizontal systems which move the length of the building are used. These systems can be cable operated or supported with aluminum track and movable low friction pulleys (Figure 5).

The system stores all the material at the end of the greenhouse which overcomes the problem of storage along the inward sloping wall. Another commercial system, used for daylength control for flowers, utilizes linear motors which operate within the aluminum track instead of cable drive.

Materials

Various types of blanketing materials have been tested for energy conserving ability. Several studies have shown the following:

- Reflective materials can save somewhat more energy than other opaque materials.
- High humidity and disease have not been a problem in houses with either porous or non porous blankets. However, moisture does condense heavily on cold roof surfaces and rains onto the plants when the blanket is opened.
- Fabric life will vary with the type of greenhouse covering. More ultraviolet penetrates polyethylene than glass causing a polyethylene cover in a polyethylene house to decompose faster than in a glass house.
- Material flammability or flame resistance varies greatly and may affect insurance rates.
- Tear strength, particularly at the seams, and fabric weight also are important. A light weight fabric may require less mechanical equipment but more frequent replacement of the blanket.



Condensation

When a blanket is used, moisture frequently condenses onto the cold roof covering and drips onto the blanket. Then, this moisture rains onto the plants as the blanket opens. This problem is more severe on curved roofs than on steep gable roofs because the condensation does not run to gutters along the sides. Some operators have applied a special wetting agent (Sun Clear) to the roof covering to make more of the condensation run to the sides and reduce the problem.

Savings with blanket use depend on:

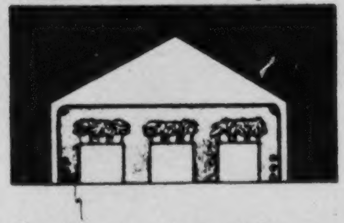
- tightness of blanket seal
- operating temperatures
- condition of greenhouse
- ratio-blanket surface area to greenhouse surface area
- blanket material

Installation

The actual savings in any greenhouse depends upon many variables. Tightness of seal around the blanket edges, physical condition of the greenhouse, operating temperatures for the greenhouse, ratio of blanket surface area to greenhouse surface area, and construction materials for both greenhouse and blanket are some of these variables.

Heat loss from air infiltration represents about 60 percent of the total in a typical greenhouse. It is very important to install a blanket that will seal tightly around all edges to effectively reduce infiltration losses.

Another major installation problem in any greenhouse is storage of the blanket during the day. All blankets take space from the plant growing area. A system that gives minimum shading and minimum interference with daily activities is desired.


Insulating curtains or blankets reduce heat loss at night

Heating source must be inside the curtained area.

Heater Location

Heat distribution systems **must** be located within the blanketed area. In heavy snow areas safeguards must be provided to prevent structural damage from snow accumulation. A special snow load sensor and alarm system can be installed to alert the operator to open the blankets and get more heat to the roof for snow melting.

Retrofitting

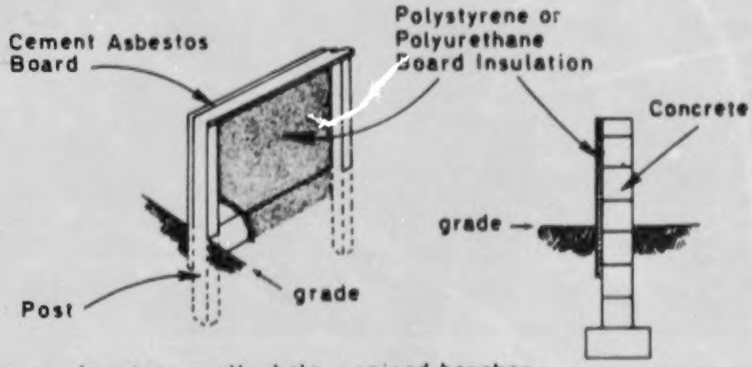
A basic problem with mechanical blanketing systems is that they must be designed for each greenhouse. New greenhouses can incorporate these features into the design, but retrofitting presents a formidable obstacle. Interior posts, low ceilings, heat distribution systems, and hanging equipment are common interferences.

Delayed Opening

In a tight system, the attic above the blanket may reach temperatures near or below freezing. When the blanket is first opened, a down rush of cold air may injure certain crops. This problem can probably be overcome by using a time delay relay which would allow the blanket to open a few inches but delay its full opening for 15 to 30 minutes. The delay allows warm air to rise and mix with the attic air before the blanket is fully opened.

Permanent Wall and Roof Insulation

Fiberglass batts or blankets and rigid polyurethane or polystyrene boards can be used to insulate walls below raised benches. Older



Insulate walls below raised benches

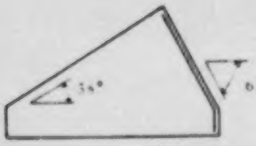
greenhouses which have leaky sidewalls or houses which have heat pipes along the sidewalls gain additional benefit from this procedure. Cover with aluminum foil laminated to paper to reflect light and radiant heat back into the house.

Heat loss through a ¼ inch asbestos-cement board sidewall can be cut nearly in half by applying ¼ inch DuPont microfoam or Sealed Air Corporation Aircap,—a plastic material with trapped air bubbles. The life of these materials depends on how they are applied and protected from mechanical damage.

North Wall Insulation

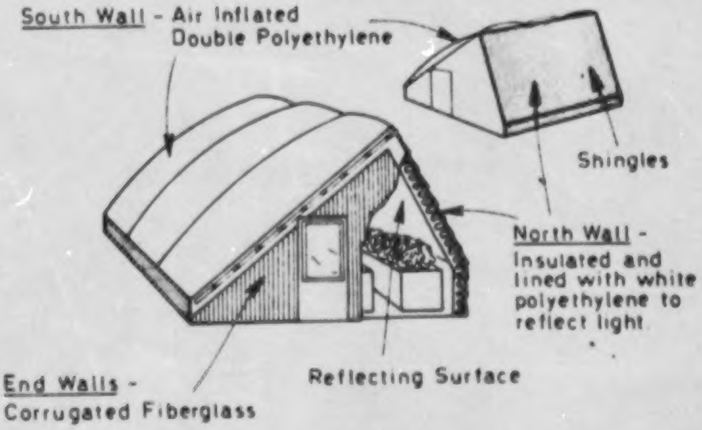
Recently, interest has developed to insulate and cover the north wall of greenhouses with reflective material. In a study at Cornell University heat use in a 36 ft × 36 ft glass house with north wall and partial north roof reflective insulation was measured to be 29% of an identical house with no insulation. Much of this improvement was due to greatly reduced air infiltration.

Researchers in Quebec have suggested installing an insulated sloping north roof-wall that has a reflective surface. This roof-wall undoubtedly reduces heat loss through the wall and reflects back some light. Reduced head room on the sides may limit the growing area, however. Also the high peak will be 10° to 20°F warmer than the plants. This strong temperature stratification plus the less accessible growing area may offset any fuel savings resulting from insulating the north wall. Cornell researchers have constructed such a roof-wall and are investigating this idea further.

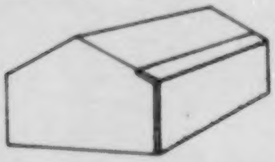


Light reflects off north wall

Experimental Greenhouse with North Wall Insulation


South Wall - Air Inflated Double Polyethylene
Shingles
North Wall - Insulated and lined with white polyethylene to reflect light
Reflecting Surface
End Walls - Corrugated Fiberglass

Reduce heating costs by insulating the north wall



Line interior with reflective material to increase light

North wall and lower sidewall insulation can substantially lower heating costs in small, freestanding greenhouses. However, these insulating techniques offer little or no savings for large ridge and furrow greenhouses. A heat loss and cost analysis should be run to help decide where insulation will pay.

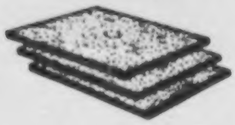
Foamed Liquid Insulation

Foam is being pumped between layers of a double polyethylene covered greenhouse at the University of Arizona. Heat loss was reduced by 47% from a U value of 0.7 Btu/hour sq ft °F to U = 0.37. Operating techniques must be refined before this method can be used on a large scale.

Bead Insulation

Another idea being tried at Ohio State University is pumping polystyrene beads between double layer polyethylene at night and sucking them out in the morning. Several problems that have not been overcome include: the entire cavity does not fill without some beads escaping, a large storage is required for the beads, and the beads statically cling to the surfaces so the cavity can not be completely emptied.

Rigid Insulation Board



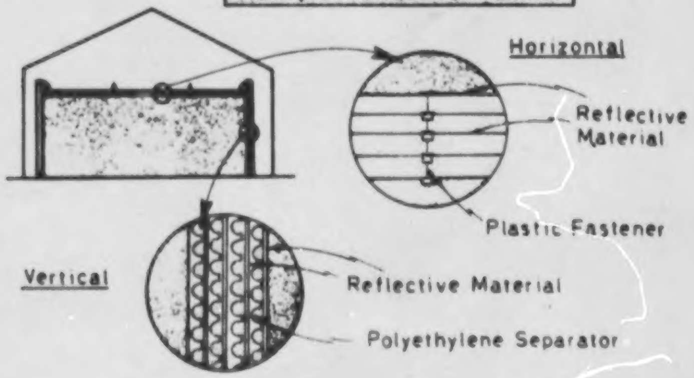
Movable Insulation Boards

A Pennsylvania State University project is evaluating a movable rigid insulation boards cover. Serious mechanical and shading problems have not been overcome.

Multiple Reflective Layers

Cornell researchers have fabricated a blanket made with several layers of reflective materials that are held apart to create airspaces. This multi-layer blanket can be rolled or folded into a small space for daytime storage, but the airspaces created when it is rolled out at night reduce heat flow dramatically. A four-layer blanket should equal the insulation value of a 2 inch fiberglass batt. Preliminary studies suggest that a 5 layer blanket may reduce the night time heat loss as much as 95%.

Multiple Reflective Blanket



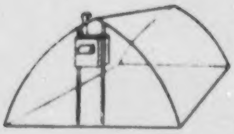
Other Conservation Techniques

Efficient Heater Operation

Other means of reducing energy use in greenhouses involve good management techniques. The following ideas are a few of the ways to reduce fuel costs:

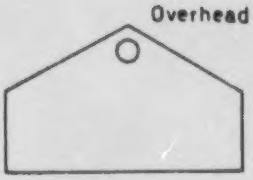
Keep heating equipment operating efficiently. This simple step can reduce heat bills 5 to 20%. Specifically:

- Have furnaces cleaned and adjusted every year. Replace old heaters.
- Check the accuracy of thermostats with an accurate thermometer. They should be accurate to within a degree. Use a small fan to blow air across the thermostat for more uniform control.
- Insulate distribution system or hot water pipes where heat is not needed. Repair any leaks. Operate boiler according to manufacturer's recommendations to prevent buildup of scale.
- Have the system checked to see if any modulating temperature controls have been or can be installed.
- Clean heating pipes and other heating surfaces often.
- Install the proper sized heating system. A heating system that is too large or installed so that heat is not directed toward the plants can use twice as much heat as a well designed and properly installed system.



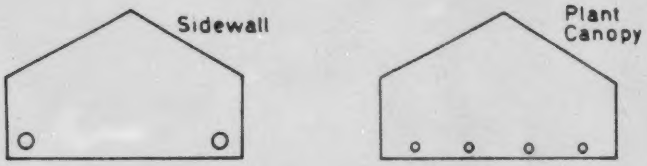
Installing Ducts

Consider installing heat distribution ducts in houses that use space heaters and are larger than 150-200 square feet in floor area. Ducts are used to obtain more even distribution of warm air and to conserve heat by directing warm overhead air near the peak to the plants.



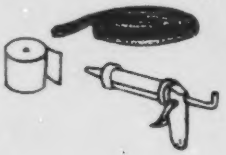
If you make your own perforated tubing, punch or burn air outlet holes with a sharpened or heated pipe every foot or two along the tube. The tube diameter should be the same as the fan diameter. The combined area of the punched outlet holes, in square inches, should be 0.15 times the air flow of the fan in cubic feet per minute (cfm). For example, if 50 outlet holes are punched in a tube for a 5000 cfm fan, each hole should have an area of $5000 \times 0.15/50 = 15$ sq. in. or a diameter of 4⅜ inches.

The heater and tubing may be mounted overhead to direct warm air over the plants or they can be placed along a sidewall. Orient the air outlet holes so that air flows out horizontally or toward the plants. Never aim the holes toward the greenhouse covering because high heat losses occur.



Ducts distribute warm air uniformly and conserve heat.

Reduce Air Leaks



Install greenhouse covering tightly and with no gaps or holes. Patch any tears in plastic and replace broken glass to reduce heat loss by 3 to 10%. Weather strip doors and keep them closed. Use door closers or springs. Lubricate any ventilation louvers so they close tightly. Close gaps under the foundation of plastic covered houses.

Ventilation

Improperly set or malfunctioning thermostats can cause the greenhouse to be cooled below the desired temperature. Excessive ventilation causes heaters to run longer to warm the incoming air. Proper maintenance of the thermostat and proper sizing of ventilation fans will reduce this problem.

Electrical Equipment

- Have the wiring system inspected for overloading, corroded parts and faulty insulation. Losses of electric energy to heating of wires can be reduced by using larger wire sizes.
- Size motors for the job and turn them off when not needed. Keep proper belt tension.
- Use larger diameter fans with smaller motors.
- Keep light bulbs and fixtures clean. Use the correct size light bulb for the job. Turn off lights when not needed.

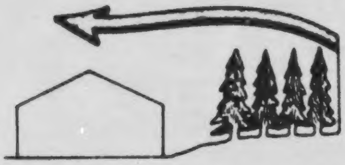
Water Supply

- Practice water conservation to keep pumping costs down. Service the pump at least twice a year. Repair all leaks.
- Use large pressure tanks to reduce the number of pump starts. Drain tanks when needed to maintain the proper volume of air in the tank.
- Locate hot water tanks as close as possible to the area using the most hot water. Heat water to the lowest temperature needed. Insulate the heater and hot water pipes.

Site Selection

Potential saving of 5 to 10 percent is possible by locating new greenhouses in sheltered areas to reduce wind-induced heat loss. Heat loss from a glass greenhouse in a 15 mph wind is double what it would be in still air. The loss is not as great in fiberglass and plastic houses, but still can be significant. When selecting a site, check that the surrounding shelter will not reduce available light.

Provide shelter on the north and northwest sides of the greenhouse site. A shelter belt with at least 4 or 5 rows of evergreen trees provides good permanent protection.



Provide shelter from prevailing winds.

Commercial snow fence, such as one inch thick boards on woven polypropylene netting, also will provide protection. A porosity of 50 to 60 percent is best. For a typical greenhouse with a ridge of 11 to 14 feet, a 10 to 12 feet high fence will give good wind reduction for up to 300 feet down wind. Place the fence 40 to 60 feet away from the greenhouse to the windward side. Six inch top diameter posts spaced 10 feet apart and set 4 feet into the ground are needed to support the fence.

Closing During Winter

Close the greenhouse from December 1 to March 1. The practice reduces fuel use to as much as one-half that needed for a year's operation. If the greenhouse is closed in winter, remove heavy snow from the roof so it will not collapse. Water pipes should be protected from freezing.

Lower Temperatures

Table 2 shows potential fuel savings when the greenhouse temperature is lowered. For example, lowering the thermostat from 65° to 55°F when the average monthly temperature is 28°F, reduces fuel consumption by 26 percent.

Table 2: Percent Reduction in Fuel Use when Greenhouse Temperatures are lowered.

		Inside Greenhouse Temperature Reduction from A to B					
Average Outside Temperature	A. B.	65° to 60° %	65° to 55° %	60° to 55° %	60° to 50° %	55° to 50° %	55° to 45° %
20°		11	22	12	24	14	28
24°		12	24	14	28	16	32
28°		13	26	16	32	19	38
32°		15	30	18	36	22	44
36°		17	34	21	42	26	52
40°		20	40	25	50	33	66
44°		24	48				
48°		29	58				

Because lower temperatures slow growth and reduce production, a careful analysis should be made before night temperatures are lowered. A study on potted chrysanthemums at Rutgers University projected that production would be reduced too much to offset fuel savings when night temperatures are dropped from 62° to 58°F.

Improve Space Utilization

Only 60% to 70% of the ground area in many greenhouses is used for actual crop production. Improving the bench layout, installing 18" aisles and eliminating equipment or activities which do not require greenhouse siting can increase this productive area to 70% to 85%.

Double cropping can sometimes be used to more effectively use the greenhouse space. Foliage plants which require low light intensity can be grown on benches with shelves of other plants above. Water and fertilizer should not be allowed to drip on plants below. And both crops should have the same temperature requirements.

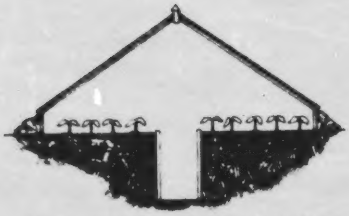
Auxiliary Buildings

Insulate and tighten up auxiliary buildings such as packaging areas, potting sheds, maintenance buildings, offices, etc.

Additional Hints for the Hobby Greenhouse

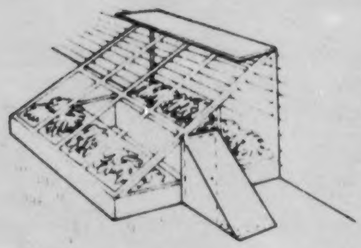
All these ideas apply to the small hobby greenhouse grower as well as the commercial grower. Often, in fact, a greater percent is saved when these ideas are applied to a smaller greenhouse. Some additional ideas for the hobbyist include:

- Build a pit greenhouse and grow cool temperature crops. The pit greenhouse is built partially below ground (4 feet or so), often attached to another building, roofed with transparent material that faces south, and normally heated only by the sun. It is less expensive to build and heat than many of the above ground styles. The surrounding earth will keep it cool, but usually above freezing. Ventilation is poor, so this greenhouse is not best for summer use. Properly installed drain tile or a sump pump should be installed for drainage.



Heat stored in the soil keeps pit greenhouse temperatures above freezing

- Build an attached greenhouse. Because less of its surface is exposed, an attached greenhouse uses less heat than a freestanding house with the same floor area.
- Some owners insulate the north side of the greenhouse and cover it with reflective material to increase light during the winter. This simple step will pay for itself in 1 or 2 years by reducing air leaks and providing greater insulation. Savings of 25-50% are possible in small greenhouses.



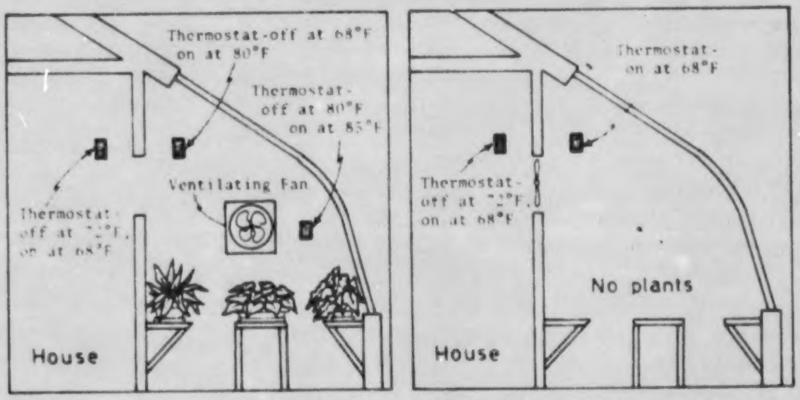
Attached
Pit Greenhouse

Combined Greenhouse/Residence

Can a greenhouse attached to the residence enhance the heating system of both? During sunny days a fan or large opening between the two can help heat the residence. But don't expect the greenhouse to collect substantial amounts of heat for the home if plants are kept in it during the winter months. In fact, heat is required by the greenhouse on winter nights. Also, air introduced from the greenhouse may be too humid and contain objectionable odors and insects associated with growing plants.

A better scheme is to remove plants from the greenhouse during winter months, so the greenhouse need not be heated at night. Then install a fan with a gravity louver to circulate warm air from the greenhouse into the residence on sunny days. A thermostat can be used to turn this fan on when greenhouse temperatures exceed 80°. Another thermostat in the residence can be wired to turn off the fan if temperatures get too high.

A large opening, such as a sliding glass door, may be used instead of the fan. The door is opened when the greenhouse is warm during the day and closed at night. During warmer months, when plants are kept in the greenhouse, a ventilating fan or mechanical vents bring outside air into the greenhouse to keep the temperature from exceeding 85°F.


Thermostat-off at 68°F on at 80°F
Thermostat-off at 80°F on at 85°F
Thermostat-off at 72°F, on at 68°F
Ventilating Fan
House
Thermostat-on at 68°F
Thermostat-off at 72°F, on at 68°F
No plants
House

The attached greenhouse can be used to supplement house heat

Cost Analysis for Modification

The price of oil, gas or electricity is important, but it is not used directly in comparing conservation techniques. Instead, the heat content per unit purchased is used to compare fuels. Fuel prices are often discussed in terms of cost per therm, which is 100,000 Btu's (British thermal units).[1] Table 3 shows the units of fuel per therm for two heater efficiencies. Multiply the current price by the appropriate fuel unit to calculate the cost per therm.

Table 3: Comparison of Heat Output from Various Fuels .

Fuel	Heat Content Btu/Unit	Heater Efficiencies	Fuel Input per Therm (100,000 Btu) Output
#2 Oil	140,000	80 - 65%	0.89 - 1.1 gal
#6 Oil	150,000	80 - 65	0.83 - 1.03 gal
Soft Coal	11,400	70 - 50	12.5 - 17.5 lb
Hard Coal	13,000	70 - 50	11.0 - 15.4 lb
Propane	85,000	80 - 70	1.47 - 1.68 gal
Natural Gas	100,000	80 - 70	1.25 - 1.43 therm

Adapted,in part, from a chart in Geo.J.Ball,Inc.,"Grower Talks",Oct 1976,p.24

The fuel saved pays for any modifications made; so an estimate of the time needed to pay for the change is useful. The following cost analysis shows how to calculate the fuel savings and annual costs of a particular conservation measure. The average daily temperature for the heating season is used in these calculations. The book, *Climate of the States*, which is available in most libraries, lists average monthly temperatures for many locations.

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[1] The British thermal unit (Btu) is the heat energy needed to raise the temperature of one pound of water 1°F. A large wooden kitchen match releases 1 Btu of heat when it burns completely.

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Sample Cost Analysis

A 20 ft × 100 ft curved roof greenhouse in the Washington DC area is presently covered with corrugated fiberglass. Will it pay to add an air-inflated double polyethylene cover?

The specifications are:

Roof area	= 3000 sq ft	
End wall area	= 300 sq ft	
Total area = A	= 3300 sq ft	
Desired inside temperature		60°F
Average outside temperature (October through April)		44.7°F
Number of days (October through April)		212 days
Fiberglass cover	U = 1.0	(from table 5)
Double poly cover	U = 0.7	
Fuel	No. 2 Fuel Oil	
Fuel Price	$0.45 per gallon	

Step 1. Gross Energy Savings

The heat loss equation may be modified to compute the difference in the two covering methods. The modified equation uses the difference in the U-values, or ΔU. The temperature difference is the inside temperature minus the average outside temperature. The total number of hours during the time period is also needed.

$$Q_T = A \times \Delta U\,(T_{inside} - T_{average}) \times \text{Time}$$

$$= 3300\,(1.0 - 0.7)\,(60 - 44.7)\,212 \times 24 \text{ hours/day}$$

$$= 77{,}100{,}000 \text{ Btu}$$

Step 2. Solar Heating Correction

The average temperature for the heating season must be modified for greenhouses because the sun radiating through the transparent cover provides some heat. Assume a 25 percent reduction in the heat loss calculated in Step 1 due to solar radiation heat.

$$Q_{TA} = 0.75 \times 77{,}100{,}000 = 57{,}800{,}000 \text{ Btu}$$
$$\text{or } 57{,}800{,}000/100{,}000 = 578 \text{ therms}$$

Step 3. Fuel Saved

A boiler operating at 65% efficiency requires 1.1 gallons of #2 fuel oil per therm (Table 3).

Fuel oil saved = 1.1 × 578 = 636 gal.

Step 4. Fuel Value

Fuel saved × price per gallon =
636 × $0.45 = $286

Step 5. Modification Cost

Double cover poly @ 3¢ per sq ft $0.03 × 2(3300)	= $198
Fasteners	90
Fan Package	20
Labor (2 people for 3 hr @$4/hr) 2 × 3 × $4.00 =	24
Total	= $332

Step 6. Annual Cost

Depreciation (Straight Line)

Item	Life	Annual Cost
Poly + Labor	2 yr	(198 + 24)/2 = $111
Fan & Fasteners	10 yr	(90 + 20)/10 = 11
	Total	$122
Interest @ 9%		122 × 0.09 = $ 11
Total annual cost of double poly cover		= $133

Step 7. Annual Net Savings

Fuel value - covering cost = 286 - 133 = $153

Heat Loss Calculations

Heat Loss Formulas

One of the first steps to a conservation program is to identify the exposed surface area that loses the largest amount of heat. Heat loss may be calculated using a conduction heat transfer equation,

$Q_C = A\,U\,\triangle T$

where Q_C = heat transfer through a material, Btu/hr

U = heat flow factor, Btu/hr °F ft²

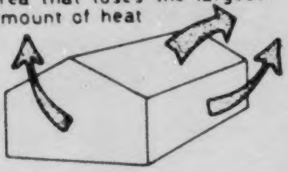
A = exposed surface area, sq ft

$\triangle T$ = temperature differential between inside and outside, °F

and an infiltration heat transfer equation,

$Q_A = 0.02 \times \triangle T \times$ greenhouse volume $\times$ number air changes per hour.

Identify the exposed surface area that loses the largest amount of heat



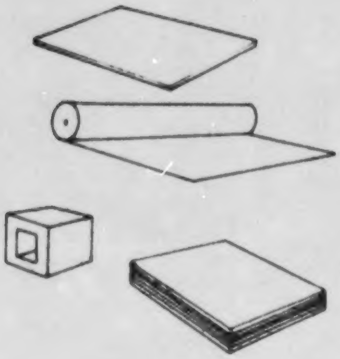
Once the major heat loss areas are found, potential changes to reduce the loss can be evaluated with a similar procedure. Materials with better heat retention characteristics are substituted and the calculations are made to evaluate the amount of heat loss reduction. Some changes will give up to 50 percent energy savings.

Table 4 lists the air infiltration that can be expected in various types of greenhouses. Table 5 lists the heat flow coefficients (U factors) for typical greenhouse coverings and insulation.

Table 4: Air Exchange for Greenhouses.

Construction System	Air Exchanges per Hour
1. New construction, glass or fiberglass	0.75 to 1.5
2. New construction, double layer PE	0.5 to 1.0
3. Old construction, glass, good maintenance	1 to 2
4. Old construction, glass, poor condition (Low wind or protection from wind reduces the air exchange rate.)	2 to 4

Table 5: Heat Flow through Various Construction Assemblies.

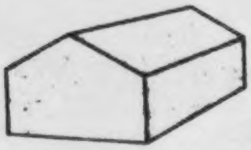


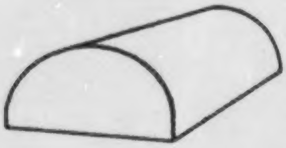
Material	U Factor Btu/sq ft °F hr
Roof and Wall Coverings	
Glass, single layer	1.1
Glass, double layer, 1/4" space	0.7
Glass, triple layer, 1/4" space	0.5
Polyethylene film, single layer	1.1
Polyethylene film, double layer, separated	0.1
Fiberglass reinforced panel	1.0
Wall Materials	
Concrete block, 8"	0.5
Cement asbestos board, 1/4"	1.1
Concrete, poured, 6"	0.8
Concrete block or cement asbestos board	
plus 1" foamed urethane	0.1
plus 1" foamed polystyrene	0.2
Soft wood, 1" nominal	0.6
Greenhouses with thin thermal blankets[a] (Aluminized material or polyethylene film)	0.4 - 0.5
Perimeter	Btu/linear ft °F hr
Uninsulated	0.8
Insulated	0.4

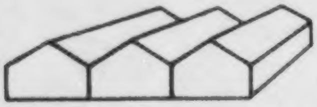
[a] Several studies have measured the U factor for greenhouses with thin thermal blankets in the range listed. It will be slightly higher in a loose house which has high infiltration losses. The value is based on the outside surface area of the greenhouse.

Worksheets

The following worksheet will help in calculating the heat loss from a single gable roof, single curved roof, or ridge and furrow greenhouse.





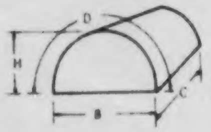


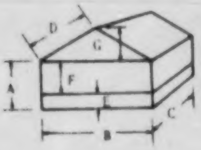
The seven steps of the calculation procedure are:

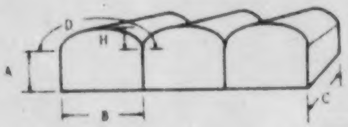
1. List dimensions.
2. Calculate surface areas.
3. List construction materials of outer surfaces and their U factors.
4. Calculate conduction heat loss.
5. Calculate the greenhouse volume.
6. Calculate air infiltration heat loss.
7. Calculate the total heat loss.

Note that floor losses are not calculated, but they can be significant in well insulated houses.

WORKSHEET—Greenhouse Heat Loss Calculations







Step 1. List greenhouse dimensions in feet

Wall height. $A =$

House width. $B =$

House length $C =$

Rafter length. $D =$

Lower wall ht., $E =$

Upper wall ht., $F =$

Gable ht., G or $H =$

Step 2. Calculate the appropriate surface areas and perimeter. N is the number of individual house sections forming each greenhouse range. N equals 1 for a single house.

Lower wall area
$2N(E \times B) + (E \times 2C) =$

Upper wall area
$2N(F \times B) + (F \times 2C) =$

Single material wall
$2N \times A \times B + 2A \times C =$

Gable area
$N \times B \times G =$

Curved end area
$1.3N \times B \times H =$

Gable roof area
$2N \times D \times C =$

Curved roof area
$N \times D \times C =$

Perimeter
$2(N \times B + C) =$

Step 3. List construction materials for each surface and U factors from Table 5.

Location	Construction Material	U Factor
Lower wall		$U_1 =$
Upper wall		$U_2 =$
Single material wall		$U_3 =$
End area		$U_4 =$
Roof		$U_5 =$
Perimeter		$U_6 =$

Step 4. Calculate appropriate conduction heat loss, Q_C.

$Q_C = \text{Area} \times U \times \Delta T$

T = Inside night temperature − Minimum outside temperature

Lower wall area $\times U_1 \times \Delta T =$

Upper wall area $\times U_2 \times \Delta T =$

Single wall area $\times U_3 \times \Delta T =$

Gable or curved end area $\times U_4 \times \Delta T =$

Roof area $\times U_5 \times \Delta T =$

Perimeter length $\times U_6 \times \Delta T =$

Total $= Q_C =$

Step 5. Calculate greenhouse volume.

Gable house volume =
$N(A \times B \times C + B \times G \times C/2) =$

Single curved roof house
Volume $= 2H \times B \times C/3 =$

Multiple curved roof Volume =
$N(A \times B \times C + 2H \times B \times C/3) =$

Step 6. Calculate air infiltration losses, Q_A.

$Q_A = 0.02 \times \Delta T \times \text{Volume} \times$ air changes per hour (Table 4.) =

Step 7. Calculate total heat loss, Q_T.

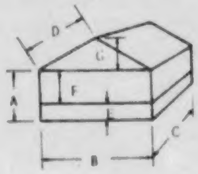
$Q_T = Q_C + Q_A =$

Sample Calculation

Calculate the expected heat loss from a single gable house covered by a single layer of glass. The house is old construction, but the glass is fairly tight. The side wall has 2 feet of cement asbestos board and 6 feet of glass. The foundation is not insulated.

Minimum desired inside temperature 60°F

Minimum expected outside design temperature 0°F



Step 1. List greenhouse dimensions in feet

Wall height. A= 8′

House width. B= 40′

House length C= 96′

Rafter length. D= 22.4′

Lower wall ht., E= 2′

Upper wall ht., F= 6′

Gable ht., G or H= 10′

Step 2. Calculate the appropriate surface areas and perimeter. N is the number of individual house sections forming each greenhouse range. N equals 1 for a single house.

Lower wall area
$2N(E \times B) + (E \times 2C) =$ $2(2 \times 40) + (2 \times 2 \times 96) =$ 544

Upper wall area
$2N(F \times B) + (F \times 2C) =$ $2(6 \times 40) + (6 \times 2 \times 96) =$ 1632

Single material wall
$2N \times A \times B + 2A \times C =$ —

Gable area
$N \times B \times G$ $= 1 \times 40 \times 10$ = 400

Curved end area
$1.3N \times B \times H$ =

Gable roof area
$2N \times D \times C$ $= 2 \times 1 \times 22.4 \times 96$ = 4300

Curved roof area
$N \times D \times C$ = —

Perimeter
$2(N \times B + C)$ $= 2(1 \times 40 + 96)$ = 272 ft

Step 3. List construction materials for each surface and U factors from Table 5.

Location	Construction Material	U Factor
Lower wall	Asbestos cement	$U_1 = 1.1$
Upper wall	Glass, single	$U_2 = 1.1$
Single material wall	—	$U_3 =$
End area	Glass, single	$U_4 = 1.1$
Roof	Glass, single	$U_5 = 1.1$
Perimeter	Uninsulated	$U_6 = 0.8$

Step 4. Calculate appropriate conduction heat loss, Q_c.

$Q_c = \text{Area} \times U \times \Delta T$

T=Inside night temperature -Minimum outside temperature

Lower wall area × $U_1 \times \Delta T$ = $544 \times 1.1 \times 60$ = 35900

Upper wall area × $U_2 \times \Delta T =$ $1632 \times 1.1 \times 60$ = 101100

Single wall area × $U_3 \times \Delta T =$ —

Gable or curved end area × $U_4 \times \Delta T =$ $400 \times 1.1 \times 60$ = 26400

Roof area × $U_5 \times \Delta T$ = $4300 \times 1.1 \times 60$ = 283800

Perimeter length × $U_6 \times \Delta T =$ $272 \times 0.8 \times 60$ = 13100

Total = Q_c = 460,300 Btu/hr

Step 5. Calculate greenhouse volume.

Gable house volume = $1(8 \times 40 \times 96 + 40 \times 10 \times 96/2)$
$N(A \times B \times C + B \times G \times C/2) =$ 49900 cu ft.

Single curved roof house
Volume = $2H \times B \times C/3 =$ —

Multiple curved roof Volume =
$N(A \times B \times C + 2H \times B \times C/3) =$ —

Step 6. Calculate air infiltration losses, Q_A
assume 1.5 air changes / hr

$Q_A = 0.02 \times \Delta T \times \text{Volume} \times$ air changes per hour (Table 4.) =
$0.02 \times 60 \times 49900 \times 1.5 =$ 89800 Btu/hr.

Step 7. Calculate total heat loss, Q_T.

$Q_T = Q_C + Q_A = 460300 + 89800 = 550100$ Btu/hr

SOLAR HEATING

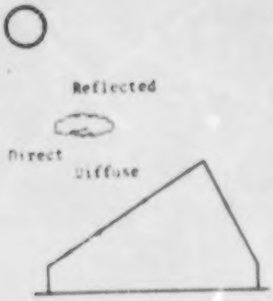
Anyone who has been in a greenhouse on a cold, but sunny, day recognizes the potential of the sun as a greenhouse heater. Even on below freezing days the ventilators must be opened to keep temperatures from soaring. If only the sun's energy could be stored for heating the greenhouse at night. Today several research projects across the country are developing ways to capture and use the sun's energy for greenhouse heating. U.S. Department of Energy funds that are administered by the USDA, are paying for part of this work.

Although the sun's energy is free, the equipment needed to collect and utilize it is not. These studies are finding usable systems to substitute for fossil fuels that are becoming either very expensive or unavailable.

The following sections cover three topics. The first reviews the nature of the sun and how it affects design of heating systems. The second identifies the equipment needed to collect and utilize the sun's energy for greenhouse heating. Finally, the third section describes several solar heating research projects.

Because the projects are new, little complete operating data are available. And while some of the equipment is described, there is little information on plumbing, electrical wiring, pumps, fans, thermostats and the many other items necessary to run a solar heating unit. However, the ideas described can help start your planning if you are considering building solar heating equipment.

Principles of Solar Heat


Reflected
Direct
Diffuse

Solar Radiation

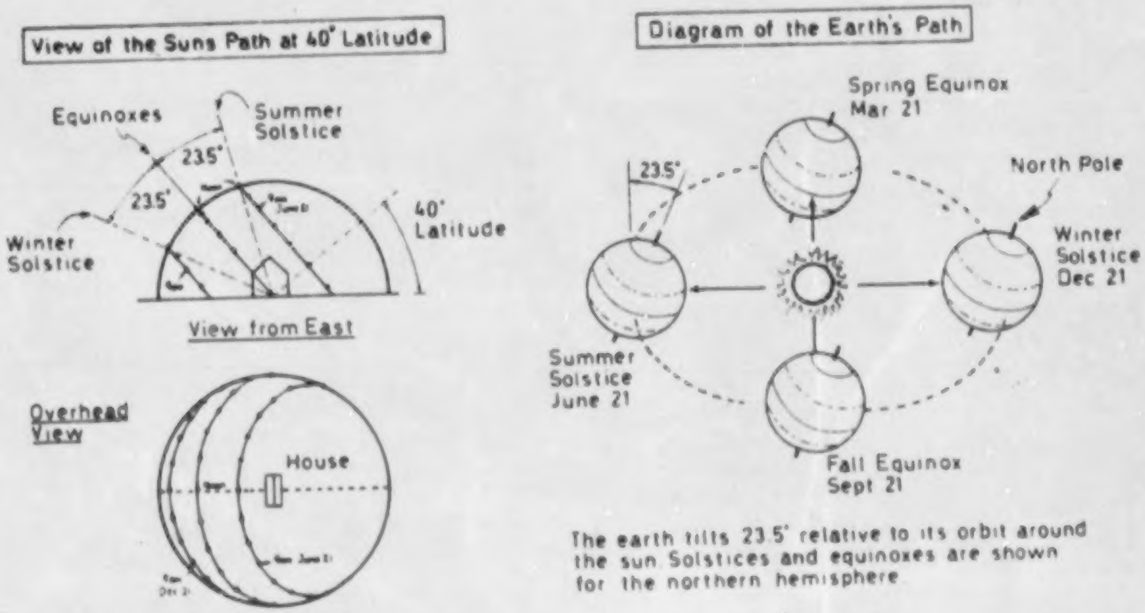
Solar energy reaches the Earth's surface by direct rays and by diffuse sky radiation, reflected from clouds and atmospheric dust. Diffuse radiation also includes radiation reflected from adjacent ground or building surfaces. The relative proportion of total radiation from these sources varies widely in each climate. Hot-dry climates with clear skies enable a large percentage of direct radiation to reach a building while up to 40 percent of the total radiation received may be diffuse in temperate and humid climates. In northern areas snow reflection from the low winter sun may result in a greater amount of incident radiation on vertical walls than in warmer, but cloudier, areas. Because of different types and amounts of radiation and different heating demands, the design of optimum solar heating components will vary in each locale.

Tilt of the Earth's Axis

The earth rotates on an axis that is tilted 23.5° with respect to its orbit around the sun. This tilt is the primary cause of seasonal changes.

Figure 6 shows the position of the sun on the first day of summer, winter, spring and fall at 40° latitude. Note that little useful

Figure 6: Diagram of the Earth's Path.


View of the Suns Path at 40° Latitude
Equinoxes
Summer Solstice
23.5°
23.5°
Winter Solstice
40° Latitude
View from East
Overhead View
House
Diagram of the Earth's Path
Spring Equinox Mar 21
23.5°
North Pole
Winter Solstice Dec 21
Summer Solstice June 21
Fall Equinox Sept 21

The earth tilts 23.5° relative to its orbit around the sun. Solstices and equinoxes are shown for the northern hemisphere radiation is available before 9:00 A.M. in the winter. Also, because the sun's angle is very low, more radiation is lost because it must travel through more atmosphere. By tilting a collection surface so it is perpendicular to the sun, more energy strikes it.

Solar Intensity

Solar radiation maps for January and July illustrate the variation of solar energy received on a horizontal surface. During the summer the Northeast receives almost as much radiation as the South. But during winter months the picture is quite different; most of the northern areas receive less than half the radiation of the South.

The maps also illustrate that the sun's energy is thinly spread and a large collection surface is needed to capture sufficient energy for heating. For example, consider an extremely well insulated greenhouse (U=0.5 Btu/hr sq ft) with 1000 square feet of surface area. If it must maintain 60°F over a 16 hour period when the average outside temperature is 30°F, about 240,000 Btu's of heat is required. A 1,000 square foot collector (assumed to have an overall efficiency of 40%) is needed to provide this heat in an area with an average solar input of 600 Btu per day. Associated thermal storage and heat exchanger devices will lower this efficiency further; so an even larger collector may be required.

AVERAGE DAILY SOLAR RADIATION
JULY
Btu/ft^2 /Day

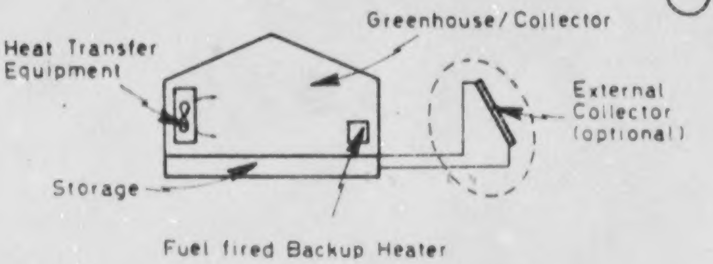
AVERAGE DAILY SOLAR RADIATION
JANUARY
Btu/ft^2 /Day

System Requirements

An effective greenhouse solar heating system requires six main components: a collector, a storage unit, equipment to transfer heat from the collector to a storage, a distribution system in the greenhouse, a back-up fuel burning heat, and equipment controls.

Some of these components may be combined to perform two or more functions. The following sections discuss these components in more detail.

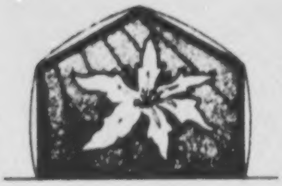
Components of a Solar Heating System



Greenhouses as Collectors

The collector converts incident solar radiation (insolation) into usable thermal energy to heat air or water. Greenhouses are natural solar collectors and some experimental ones have been modified to store heat trapped in the day for later use at night. In these modified greenhouses, a fan draws warm air from near the peak of the roof. The air is then forced through a mass of stones, typically in the floor or underneath benches, to store the heat. At night, airflow is reversed to return heat from the stones to the greenhouse.

A greenhouse-collector has several advantages over an external collector. Construction costs are less, no additional land is required, and little heat loss occurs in the transfer of heat from the collector to the greenhouse or storage.



The greenhouse has several deficiencies as a collector. At times, a greenhouse-collector must be vented to lose heat. Also some venting is required to lower humidity levels to prevent disease buildup. Because it must be vented, do not expect the standard greenhouse/collector to reduce fuel use by more than 10% to 20%. Insulation, internal blankets and double glazing should be installed to more effectively use the small amount of heat collected.

External Collectors

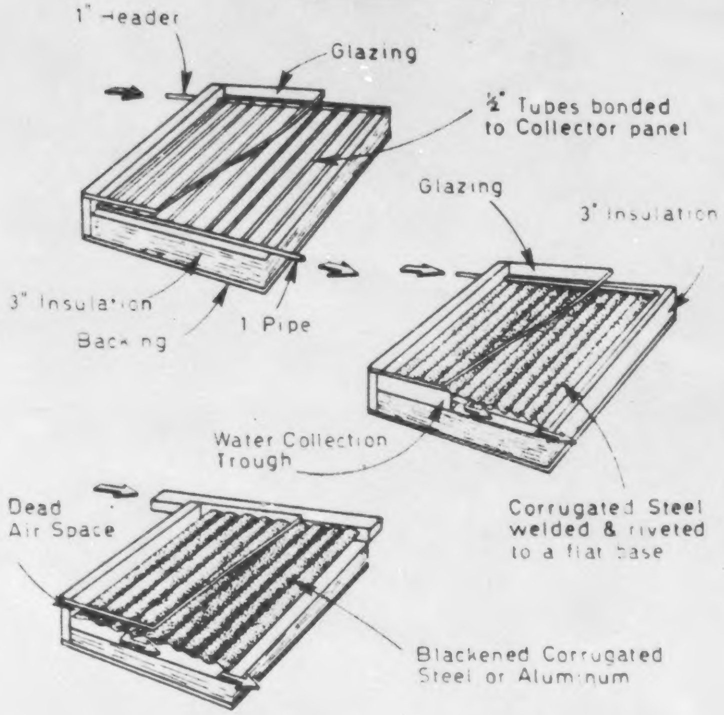
An external collector, oriented to face the sun directly, captures a higher percentage of the sun's heat and requires no venting. Various styles of **flat plate collectors** can be purchased or built to obtain higher collection efficiencies and more collection area than the greenhouse alone.

In its simplest form, a flat plate collector is a large piece of black material set to absorb the sun's rays. Heat is then transferred to water or air passing over or through it. More heat can be collected by covering the front of the collector with one or more layers of glass or transparent plastic, and insulating the back.

○ Determining Collector Size

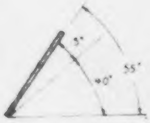
- initial cost
- collector efficiency
- total sunlight

Typical Flat Plate Collectors


1" Header
Glazing
½" Tubes bonded to Collector panel
Glazing
3" Insulation
3" Insulation
1 Pipe
Backing
Water Collection Trough
Dead Air Space
Corrugated Steel welded & riveted to a flat base
Blackened Corrugated Steel or Aluminum

Orientation

○

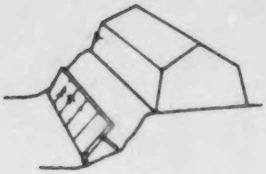


Orientation for winter heating in Philadelphia

Flat plate collectors are the most efficient when they are faced south (or within 15° of true south) and tilted perpendicular to the sun at solar noon. During spring and fall this angle of tilt with respect to the ground is the same as the latitude. On the first day of winter the angle is 23° plus the latitude. For winter heating most collectors are permanently mounted at a compromise angle of 15° plus the latitude. For example, Philadelphia is at 40° North latitude. A collector permanently mounted at 40 + 15 = 55° from the horizontal can be used to collect winter heat.

Location

A large tilted collector located adjacent to the greenhouse on the south or north side will shade plants in the greenhouse or vice versa. Shading is still a problem, but less so to the east and west of the greenhouse. Ideally a collector should be located below or far enough from the south side of the greenhouse to prevent shading.



External collectors must be positioned to prevent shading of the greenhouse.

Construction Pointers

Glass covers and metal framing stand up to the severe collector heat loads better than wood and plastic. The most severe heat loading occurs when no water or air is run through the collector during the day due to a breakdown, maintenance, or summer shut down. Collectors should either be shaded or otherwise protected during the summer.

Collectors that use water as a transfer fluid must be self draining in areas where freezing occurs. Installing a mechanical air vent at the collector inlet, sloping all lines to the storage, and insulating exposed lines will reduce this problem.

Surface Area

Optimum collector area for a given greenhouse area is not well defined. The initial cost, collector efficiency, and total sunlight available at a given location most affect the size chosen. All flat plate collectors have about the same collection efficiency at low operating temperatures. But as operating temperatures increase, the better, and usually more expensive, collectors gather more energy than less expensive ones. Also, higher temperatures allow the use of smaller and less expensive storages and heat exchangers. So the choice is not clear. A low cost, inefficient collector, operated at temperatures below 100°F, with a large storage and heat exchanger is one choice. The other is a more expensive, efficient collector, operated above 100°F, with smaller, less expensive storage and heat exchangers.

Design is still an art; but, as a start, plan at least ½ square foot of collector surface per square foot of greenhouse area. Northern areas require one square foot, or more, of collector surface per square foot of greenhouse floor area. For winter heating collectors, plan a water flow rate of 1.0 to 3.0 gallon per minute per 100 sq ft of collector surface. Air heating collectors require air flow rates of 5 to 15 cubic feet per minute per square foot of collecfor surface.

Collectors should be protected from intense summer heat loads.

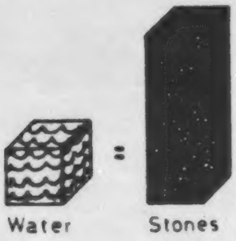
Cost

In most cases, it is still better to invest capital into more greenhouses for the available land rather than into solar collectors. At present, most external collectors cost more than the fossil fuel energy they replace. Some collectors are 5 times more costly than an equivalent sized greenhouse. Another major shortcoming is the large land area required by collectors to avoid shading the greenhouse or other collectors. Generally about two square feet of land is required for every square foot of collector area.

Storage

Heat collected must be stored for later use. Heat can be stored by warming a material such as water or small stones. Pound for pound, water can store more heat than any commonly available material. One Btu of heat will raise the temperature of a pound of water 1°F. This value is called specific heat. Rock, iron, or aluminum have specific heats of about 0.2 Btu or less per pound of material per °F temperature rise.

Deciding on a storage volume is as difficult as sizing the collectors. A rock bed for an air system must be three times larger than a water tank for the same heat storage capacity.



Storage Volume for Air System

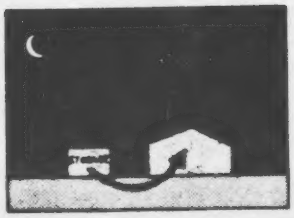
Many small stones in a given area have more surface area than a few large ones; so for a given air velocity, more heat can be transferred to the smaller stones in a given time period.

Small, ⅜ inch stones work well in large, shallow (2 to 3 ft deep) beds, while larger, ¾ to 1½ inch, stones have less impedance to air flow in deeper beds. Some systems, where air flows through 10 feet or more of bed length, use 3 to 12 inch rocks.

Stones should all be about the same size, washed, and fairly round for best results. A concrete aggregate mix of sand, pebbles, and rock is not good for solar heat storage because it has a high resistance to air flow.

For low temperature applications, figure that the temperature of the storage unit will rise only 20° to 30°F. The storage should have enough capacity to heat the greenhouse for an average winter night.

For example, a double layer, polyethylene covered greenhouse, 20 ft × 100 ft, loses about 3500 Btu per hour per °F of temperature difference between inside and out. If the average winter temperature is 35° and the inside temperature is to be kept at 60°, the average heat loss per 13 hour night is 3500 Btu/hr °F × (60°–35°) × 13 hr, or about 1.1 million Btu. A 4400 gallon water tank (6′ diameter, 21′ length) that starts the night at 110° and drops to 80° is required to store that much heat (4400 gallons × 8.3 lb/gallon × 1 Btu/lb°F × (110° - 80°) = 1.1 million Btu). A one foot deep rock storage bed under the greenhouse will also store this much heat.



The storage should have capacity to heat the greenhouse for an average winter night.

Location

There are several advantages to locating the heat storage inside the greenhouse. Any heat lost from the storage still heats the greenhouse, no losses occur when heat is circulated from the storage to the greenhouse, and little additional land is required for the storage.

In some cases, an internal storage may keep night temperatures too high in the early evening for best plant performance. Also, internal storage may not conveniently fit in a house where crops are planted directly in the soil. For these reasons, external storages or combination collector/storages may be feasible, but more expensive, alternatives.

Heat Transfer

Heat that is collected must later be efficiently transferred from the storage to the greenhouse. Systems that heat air commonly use a fan to circulate the air from the collector and through a rock bed. At night air flow is reversed by reversing the fan or by using a second fan to circulate air through the heated rocks and into the greenhouse.

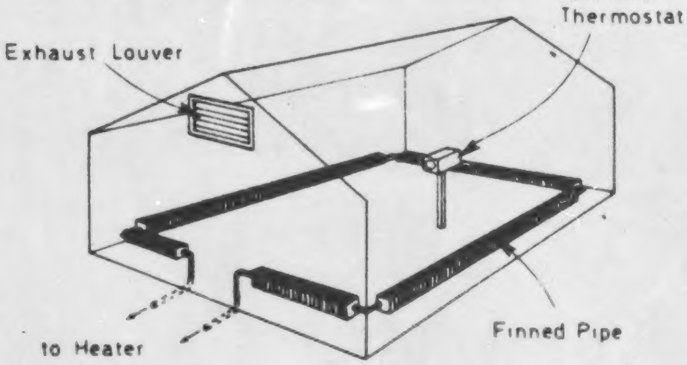
An air exchange every 2 to 4 minutes is typical. Calculate the fan capacity by calculating the total volume of the greenhouse and divide by the number of minutes for an air change. For example, a 20 ft × 100 ft greenhouse with an average height of 10 feet has a volume of 20 × 100 × 10 = 20,000 cubic feet. To exchange air every 2 minutes, a 20,000 ÷ 2 = 10,000 cfm circulating fan is required.

Heat must be efficiently transferred from storage to greenhouse

⇨ ⇨ ⇨

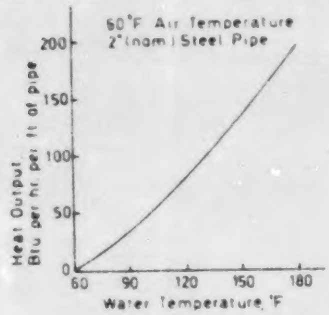
For many years, commercial greenhouses have used hot water or low pressure steam for heating. Very hot (180° to 220°) water or steam is pumped from a central fuel fired boiler to the greenhouse. Horizontal pipes radiate this heat the length of the greenhouse. Sometimes finned pipe is used to increase the pipe area so more heat per foot of pipe can be transferred. Another system uses compact unit heaters consisting of a number of coils and fins through which the water or steam circulates. A fan in the unit blows air past the coils and into the greenhouse.

Finned Pipe Hot Water Heating System



The amount of heat transferred to the greenhouse from a hot water heater or tank is almost proportional to the area of the heater surface and the water temperature. For example, 180° hot water

Heat Output from a 2" Hot Water Pipe



flowing through 100 feet of 2 inch pipe provides about 20,000 Btu — enough to raise the temperature 40° in a 12 ft × 16 ft double polyethylene covered greenhouse.

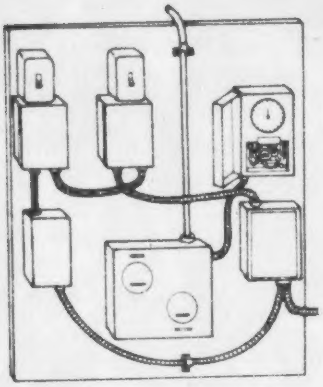
But solar heated water is typically only 100° or so. A foot of 2 inch pipe at 100° would provide only 50 Btu per hour; thus 400 feet of pipe would be needed to provide 20,000 Btu/hour in a solar heated greenhouse.

Few designs are available for large inexpensive heat transfer surfaces for warm water solar heating. And, in areas with little winter sunshine, the additional energy required to run circulating fans or pumps may cost almost as much as the collected solar energy is worth.

Controls

Once the components of a solar heating system have been selected a control system must be developed. Controlling everything to operate at the right time or temperature is a challenge. Water or air should not be circulated to the collector at night or when there is not enough sunlight to heat the fluid. To prevent freeze-ups in cold areas, water lines to and from the collector must drain freely when circulating pumps are off.

Water or air should not be circulated from storage to the greenhouse if storage temperatures are lower than greenhouse temperatures. If a heat pump is used, storage temperatures should not drop below 40°-50°F.



A typical set of controls and sequence of operations might be as follows:

Control	Function	Location
Differential Thermostat	Turns collector-storage pump on when collector temperature exceeds storage temperature by 10° and off when difference is 5°.	One sensor fastened to the collector plate near the bottom of the collector. Other sensor in storage device.
Thermostat 1	Turns storage to heat exchanger pump on at 63°, off at 65°.	In greenhouse
Thermostat 2	Turns off storage to heat exchanger pump when storage temperature is less than 80°, on at 82°.	In storage
Thermostat 3	Turns on fuel fired heating unit at 60°, off at 62°.	In greenhouse
Thermostat 4	Turns on low ventilation fan at 75°, off at 72°.	In greenhouse
Thermostat 5	Turns on high ventilation fan at 80°, off at 77°.	In greenhouse

Experimental Systems

This section describes some of the solar heating systems now being studied at various research centers across the country. Some construction ideas are shown to help you build your own solar heating equipment. But remember, these units are experimental. No solar heater will supply all the heat needed for the greenhouse. Few, if any, can heat a greenhouse more cheaply than conventional fuel fired heaters. And the greenhouse must be made to conserve energy to make the most effective use of any form of heat.

New York

At Cornell University a 22 ft × 38 ft greenhouse is equipped with four rows of combination bench-rock heat storage units. The 30 feet long benches are filled to within 5 inches of the upper cover with crushed limestone. To simplify construction, the benches were made with ten 4 feet long plywood and steel modules. A fan draws warm air near the peak of the greenhouse through an overhead tapered duct with a continuous slot opening. The warmer air is then blown into the space between the rock and the top of the bench, through the rock bed, and out through 1½ inch wide slots at the bottom of the bench. At night, air flow is reversed to allow the heated rocks to warm the greenhouse. (Figure 7). From mid-February through much of the spring the rock stored enough heat to reduce fuel use by 25%. However, during much of this period no plants were in the greenhouse, so temperatures were allowed to climb to 105°—too high for best plant growth.

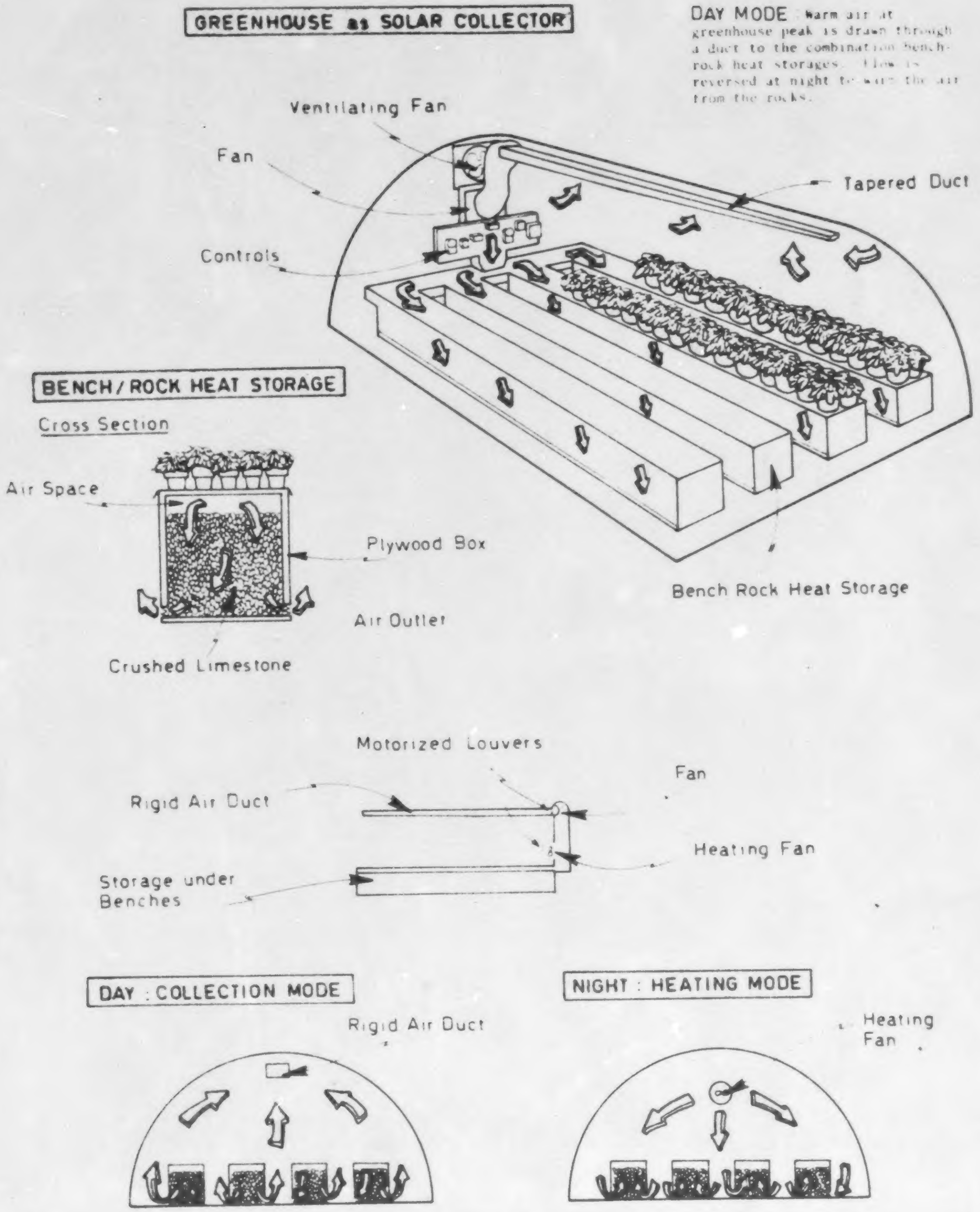
Pennsylvania

The Pennsylvania State University has done a similar study in a 20 ft × 20 ft greenhouse using underbench rock storage. Preliminary results from this collection system show that only 5% to 10% fuel savings can be obtained in uninsulated greenhouses.

North Carolina

At North Carolina State University the greenhouse aisles have been converted to a rock storage. In a January test period, 8% to 16% of the total heat needed was supplied by the solar storage unit. (Figure 8).

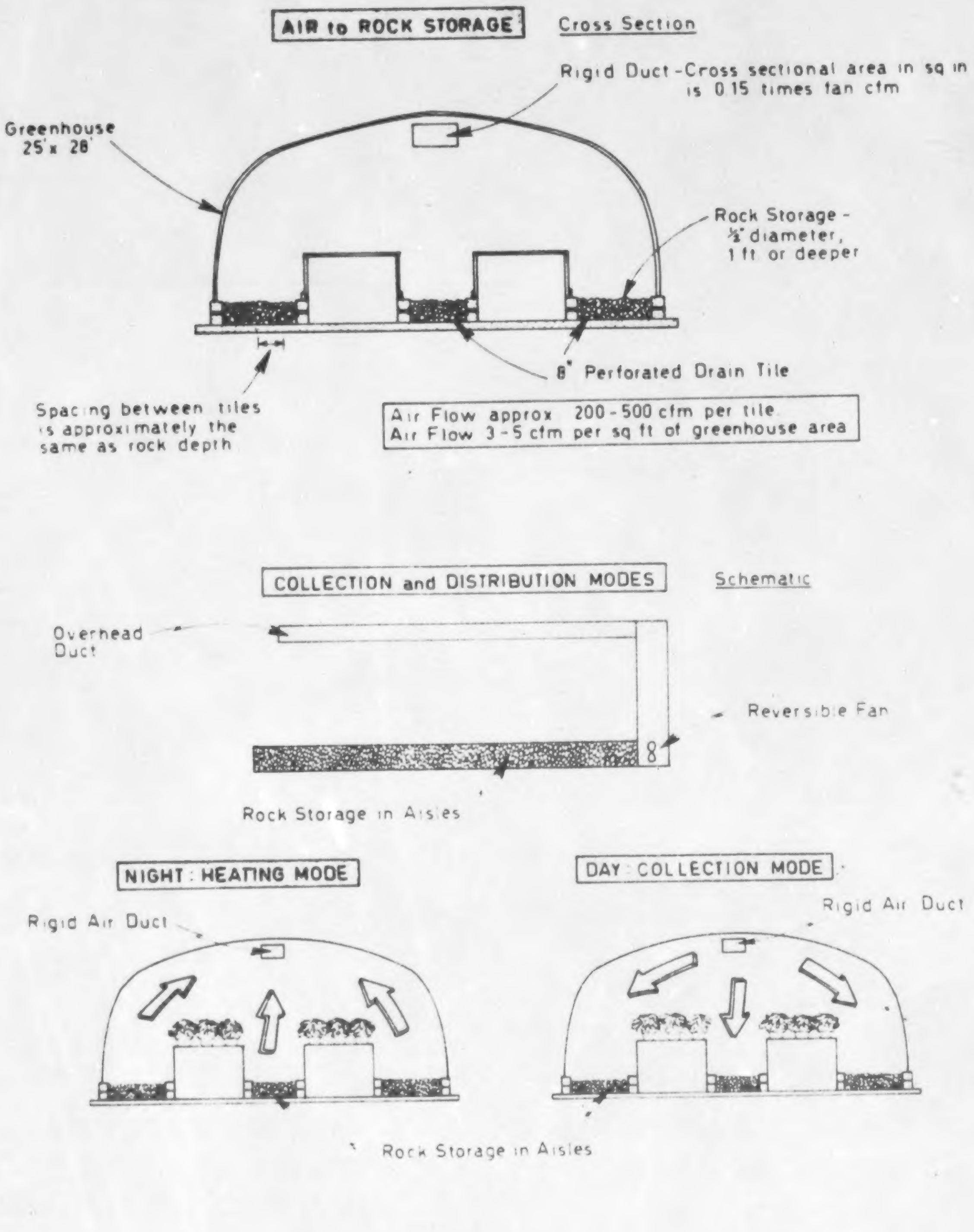
Figure 7: Cornell University Solar Heating System.



DAY MODE: Warm air at greenhouse peak is drawn through a duct to the combination bench-rock heat storages. Flow is reversed at night to warm the air from the rocks.

GREENHOUSE as SOLAR COLLECTOR
Ventilating Fan
Fan
Tapered Duct
Controls
BENCH/ROCK HEAT STORAGE
Cross Section
Air Space
Plywood Box
Air Outlet
Crushed Limestone
Bench Rock Heat Storage
Motorized Louvers
Fan
Rigid Air Duct
Heating Fan
Storage under Benches
DAY : COLLECTION MODE
Rigid Air Duct
NIGHT : HEATING MODE
Heating Fan

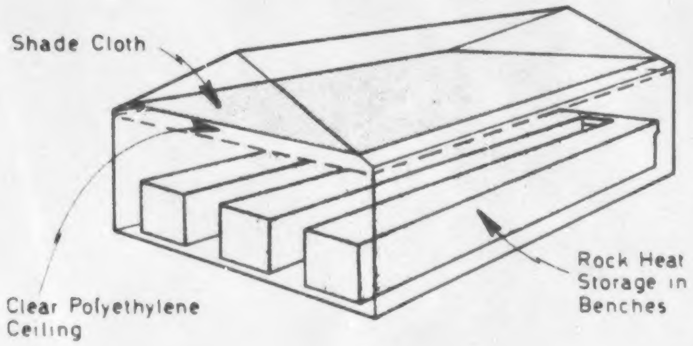
Figure 8: North Carolina State University Solar Heating System.


AIR to ROCK STORAGE
Cross Section
Rigid Duct-Cross sectional area in sq in is 0.15 times fan cfm
Greenhouse 25'x 28'
Rock Storage - ½" diameter, 1 ft. or deeper
8" Perforated Drain Tile
Spacing between tiles is approximately the same as rock depth
Air Flow approx. 200-500 cfm per tile.
Air Flow 3-5 cfm per sq ft of greenhouse area
COLLECTION and DISTRIBUTION MODES
Schematic
Overhead Duct
Reversible Fan
Rock Storage in Aisles
NIGHT: HEATING MODE
DAY: COLLECTION MODE
Rigid Air Duct
Rigid Air Duct
Rock Storage in Aisles

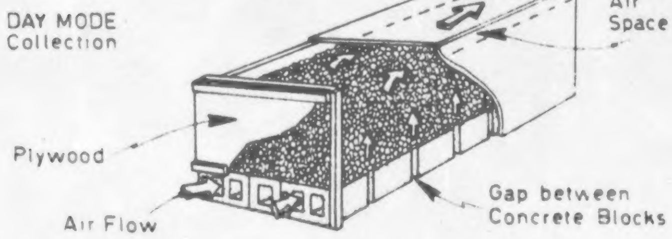
Florida

At the University of Florida an 18 inch bed of ½ inch gravel is located under 40 inch wide, 40 feet long benches in a 1450 sq. ft. glass-aluminum greenhouse. Concrete blocks with a small space between each are used as an air duct at the bottom of the gravel bed. A fan draws air from overhead and forces it through the hollow cores of the concrete block. The air passes vertically through the rock and back to the greenhouse. At night airflow is reversed.

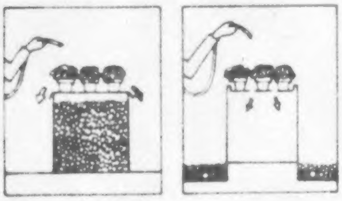
University of Florida Solar Heating System



BENCH - Cutaway



Irrigation water should be diverted from rock storages to limit weed & algae growth



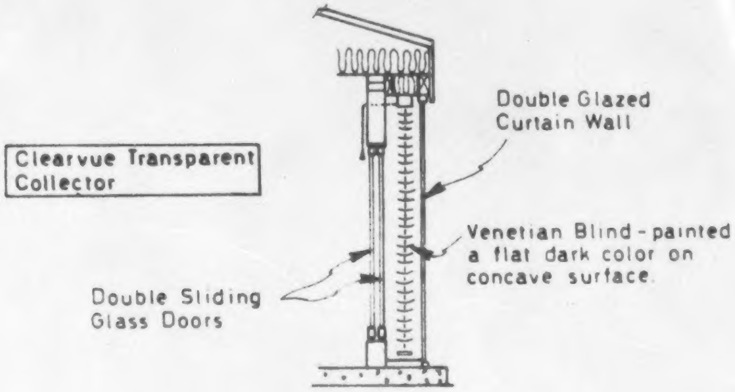
Because Florida has high light levels, a polypropylene shade-cloth that provides 25% shade is placed in the gable of the greenhouse. Then the attic is sealed with a clear polyethylene ceiling. The heat absorbed by the shadecloth and the closed space has created temperatures as high as 120°F in this attic collector. A properly designed system, for Florida conditions, is expected to maintain temperatures in the greenhouse 25° above outside temperatures. Growth of flowering and fruiting plants would be reduced if shading were used in northern areas in winter months. Also, snow would collect on the roof.

In all these projects, irrigation water is diverted from the rock storages. This practice is followed to limit weed and algae growth that would be fostered by the warm temperatures and fertilizer-enriched water. In addition, higher air pressures are required to blow air through the rocks with excessive water.

Arizona

The Environmental Research Laboratory of the University of Arizona is testing a small greenhouse/office combination. The laboratory developed the Clearvue collector in which the blackened Venetian blind absorbs heat that is transferred to air passing between the outside glass panel and the patio door inside. In addition it can be closed for privacy or to reduce heat loss from the greenhouse at night.

On clear January days in Tucson, Arizona, using standard patio door glass, the output of the collector was 650-700 Btu per square foot per day with the blinds open, and 850 Btu per square foot per day with the blinds closed. Air circulates at 4 cfm per square foot of glass area from a rock storage.


Clearvue Transparent Collector
Double Glazed Curtain Wall
Venetian Blind - painted a flat dark color on concave surface.
Double Sliding Glass Doors

New Jersey

Rutgers University in New Jersey is making extensive use of plastic films for collectors and heat transfer systems. Water warmed by external collectors is stored under a unique greenhouse floor. At night special polyethylene film heat exchangers are raised to provide more heating surface. A backup water heater is used when more heat is needed. An air inflated double polyethylene cover and automatic blanket system that is pulled over the crop at night are used to reduce heat losses.

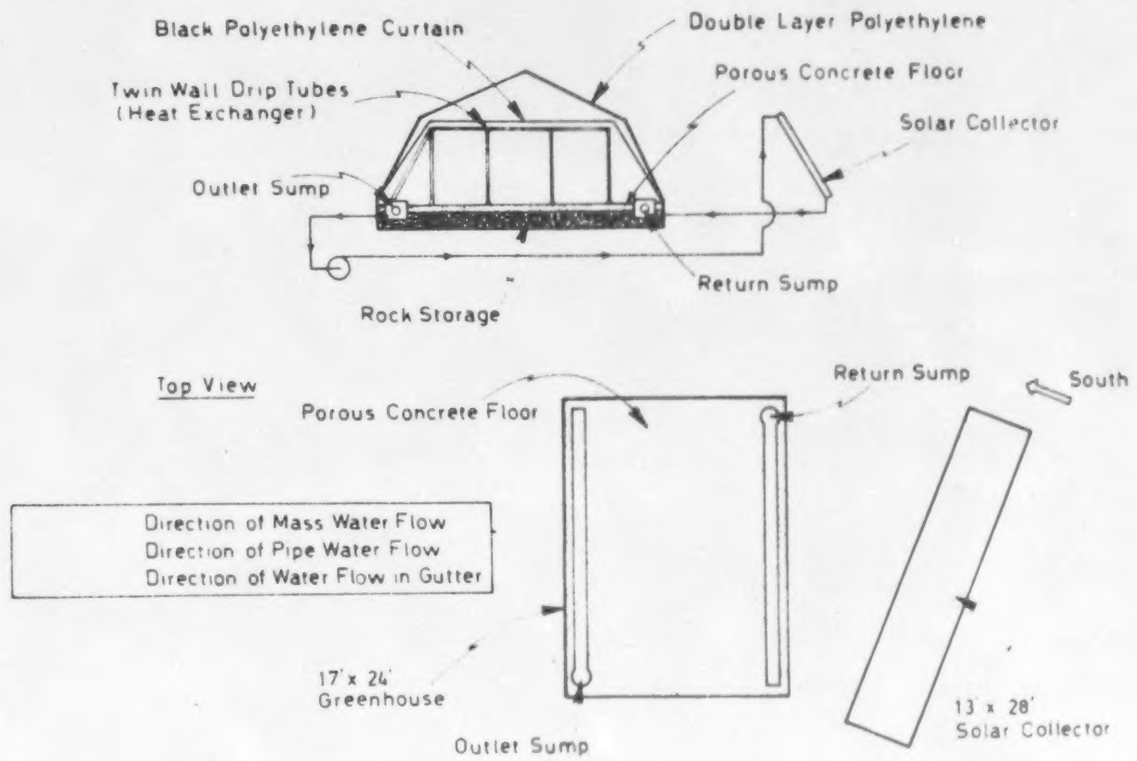
Collection

The 10 feet high, 24 feet long collector is designed so the angle can be adjusted. The four layers of 6 mil clear, ultraviolet stabilized plastic and one layer of black polyethylene are arranged to provide structural stability and some insulation. The black layer is sandwiched between two air inflated sections of clear film. A recent design has been developed that uses standard metal greenhouse framing.

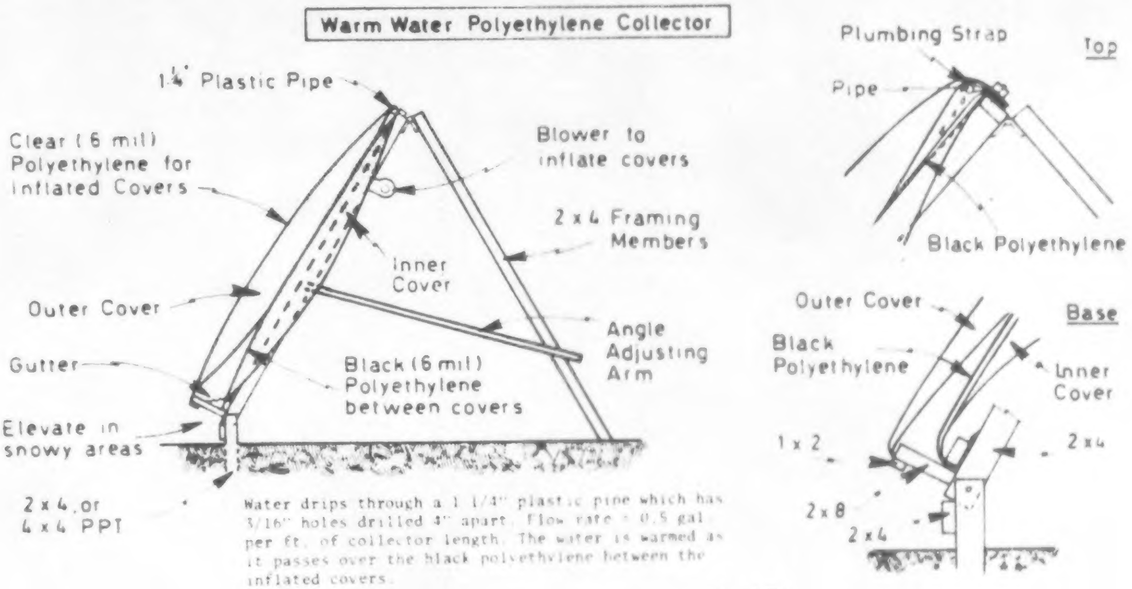
Figure 9: Rutgers University Solar Heating System

Schematic

Collection and Storage System


Black Polyethylene Curtain
Double Layer Polyethylene
Twin Wall Drip Tubes (Heat Exchanger)
Porous Concrete Floor
Solar Collector
Outlet Sump
Return Sump
Rock Storage
Top View
Porous Concrete Floor
Return Sump
South
Direction of Mass Water Flow
Direction of Pipe Water Flow
Direction of Water Flow in Gutter
17' x 24' Greenhouse
Outlet Sump
13' x 28' Solar Collector

Warm Water Polyethylene Collector


1¼" Plastic Pipe
Clear (6 mil) Polyethylene for inflated Covers
Blower to inflate covers
2 x 4 Framing Members
Inner Cover
Outer Cover
Angle Adjusting Arm
Gutter
Black (6 mil) Polyethylene between covers
Elevate in snowy areas
2 x 4 or 4 x 4 PPT
Plumbing Strap
Top
Pipe
Black Polyethylene
Outer Cover
Base
Black Polyethylene
Inner Cover
1 x 2
2 x 4
2 x 8
2 x 4

Water drips through a 1 1/4" plastic pipe which has 3/16" holes drilled 4" apart. Flow rate = 0.5 gal per ft. of collector length. The water is warmed as it passes over the black polyethylene between the inflated covers.

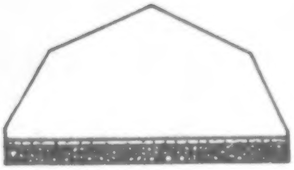
The dead air space created by the two air inflated sections acts as a modest insulator. Greater insulation on the back is not recommended. Ideally, water always runs through the collector to keep it from getting too hot; but breakdowns, maintenance periods and summer shut downs occur to stop water flow.

Water is pumped to the top of the collector where it leaves the 1½ inch pipe through ⅛ inch diameter holes spaced 6 inches apart. Water flows down between the rear layer of the front inflated section and the black layer, is collected in a trough, and returned to storage. Sheet flow is encouraged because the clear film is forced against the black film by the small blower with a static pressure of about 0.25 inch of water. Further improvement in sheet flow is achieved by adding a small quantity of detergent to the water.

Flow rates in the experimental collector varied from 0.3 to 0.5 gallons per minute per foot of collector length. Temperature records indicate the following on a clear November day:

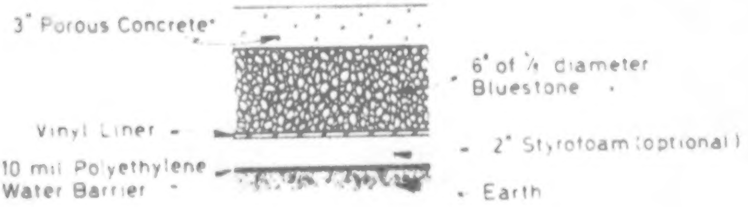
Time	Flow Rate, GPM	Inlet Temp., °F	Outlet Temp., °F	Collected Insolation Btu/hr ft²	Efficiency
10:00	14.3	77	82	149	[illegible]
11:45	14.3	97	102	149	[illegible]
13:45	14.3	106.5	110	104	[illegible]

Storage



Warm water from the collector is stored under the greenhouse. The key to this design is the porous concrete floor. A relatively recent idea, it is being accepted as a floor system by some greenhouse growers. The concrete is made with aggregate, cement and water, but with no sand. The formula is 2800 pounds of ⅜ inch aggregate, 5½ to 6 bags of cement and 15 to 18 gallons of water per cubic yard of mix.

Porous Concrete Floor Cross Section



3.7 gallons of water / cu. ft. of rock
[illegible] Btuh / ft² °F

* Mix for one yard of concrete: 2800 lb. of ⅜" aggregate, 6 bags of cement, 15-18 gal. water, no sand

There are several advantages to the grower. No weeds can grow in the house and carts can be used over the entire floor area. Perhaps the greatest advantage occurs when using automatic irrigation or misting systems, the excess water drains through the floor.

The warmed floor serves as both storage and heater. The porous concrete with a rock aggregate mass underneath provides space for storing 3.7 gallons of water per cubic foot. The water-rock floor transfers approximately 1.5 Btu of heat per hour per square foot of floor area per °F temperature difference between air and floor.

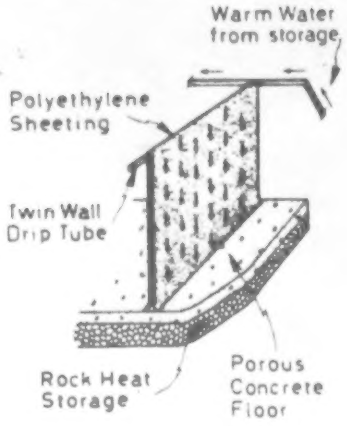
Polyethylene tubing can be run back and forth in the rock bed on 2 feet centers and connected to a hot water boiler, which is used as a back-up heater.

The rock filled, porous concrete floor should keep bedding plants warm enough in most areas without supplemental heat exchangers. An internal blanket must be installed to retain this low level heat, however.

Heat Exchanger

Rutgers is testing an exchanger that consists of a single sheet of polyethylene draped over a supporting member and hangs down to the floor on each side. A trickle irrigation, double-chamber drip tube is attached to the supporting member under the film. Warm water, pumped from the floor storage into the double chamber tube, flows by gravity between and down the inside surfaces of the plastic sheet onto the floor.

Polyethylene Heat Exchanger



The heat transfer coefficient is about 1.5 Btu per hour per square foot of plastic surface per degree (F) of temperature difference between the water and the air temperature in the greenhouse. The plastic exchangers can be elevated or dropped during the day to avoid shading the crops. Evaporation is limited because the water runs between the layers of film.

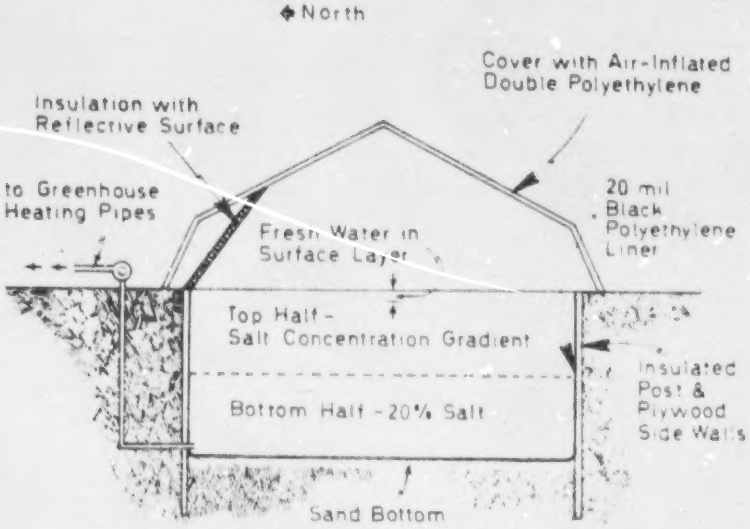
For example 80°F water in a 60°F greenhouse would provide 1.5(80 - 60) = 30 Btu per hour per square foot. To provide 10,000 Btu per hour, 10,000 ÷ 30 or 333 square feet of surface is needed. Since the plastic is doubled to drape over the tube, the total amount purchased is twice this area. It may be difficult to provide enough surface area for heating except in mild climates.

Ohio

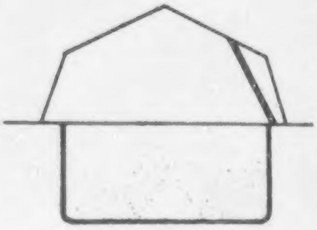
An unusual pond that both collects and stores solar energy is being studied at the Ohio Agricultural Research and Development Center. This 12 foot deep 28 ft by 60 ft pond is being used to heat a 1,000 square foot greenhouse.

Typical pond construction is shown in Figure 10. The cover (1) helps insulate the pond, (2) reduces dirt and trash that interfere with light transmission, (3) quiets the surface to reduce light scatter and mixing of the brine, (4) reduces water evaporation loss, and (5) keeps out rain water.

Figure 10: Typical Solar Pond Construction.


North
Cover with Air-Inflated Double Polyethylene
Insulation with Reflective Surface
to Greenhouse Heating Pipes
20 mil Black Polyethylene Liner
Fresh Water in Surface Layer
Top Half - Salt Concentration Gradient
Insulated Post & Plywood Side Walls
Bottom Half - 20% Salt
Sand Bottom

A 20 mil thick vinyl swimming pool liner makes a good pond liner. It must be carefully installed to prevent punctures. There are no consistently effective ways to identify and patch these leaks without draining the pond.



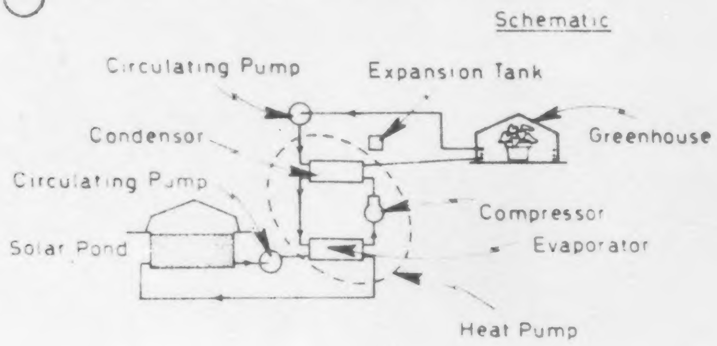
The bottom half of the pond is a 20% salt (sodium chloride) solution that stores the heat. The top half has a concentration gradient that varies from fresh water at the top to 20% salt at the 6 foot depth.

The solar pond is heated by solar radiation passing through the saltwater to the black liner holding the liquid. As the black liner temperature increases, heat is transferred to the 20% brine in the bottom half of the pond. The heated 20% brine rises no higher than the bottom layer of the gradient and cooler 20% brine moves down to replace it. The upper water layer helps insulate the pond, but allows almost all the sun's ultra-violet and visible radiation to pass through. Still water is a good insulator with four feet of water equal to a 3 inch fiberglass insulation blanket.

Theoretically, both summer and winter radiation can be collected and stored for later use. After a full summer's radiation, the pond temperature throughout the bottom half should approach boiling. At present, the Ohio pond has not exceeded 140°F.

The warm brine at the bottom can be pumped directly to heating pipes in the greenhouse. Unfortunately, at brine temperatures below 120°F, the length (or area) of pipe needed for heating at this low temperature becomes excessive. The Ohio system uses the solar pond to assist a heat pump system.

Solar Pond Heating System

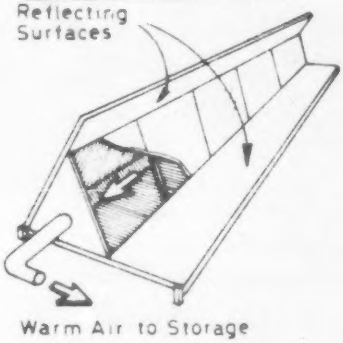


Indiana

Purdue University researchers are circulating air from an external collector through 56 four inch diameter plastic pipes that are buried in an insulated pit filled with water saturated soil. Air from the greenhouse is warmed by circulating it through these pipes. Control louvers direct the air flow for proper operation.

A 64 foot long air heating solar collector, with reflector panels, similar to that shown in the figures, circulates air through the triangular A-frame section and into storage. A blower with a capacity of 50 to 100 cfm per foot of collector length can be used.

Concentrating Collector

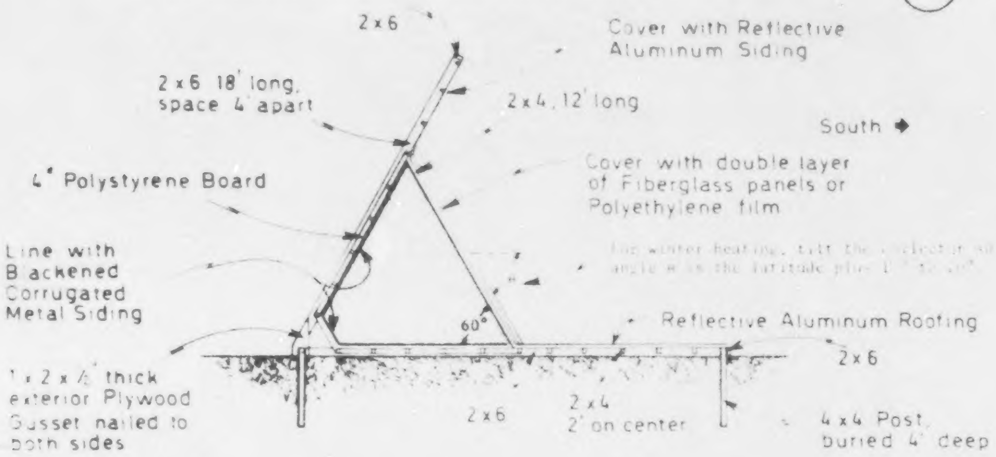


The 36 ft × 72 ft × 8 ft deep storage pit has a volume of 14,500 cubic feet. It has a heat storage capacity estimated at about 45 Btu per cubic foot of volume for every degree (F) temperature rise. At present, the storage has not retained heat as well as expected.

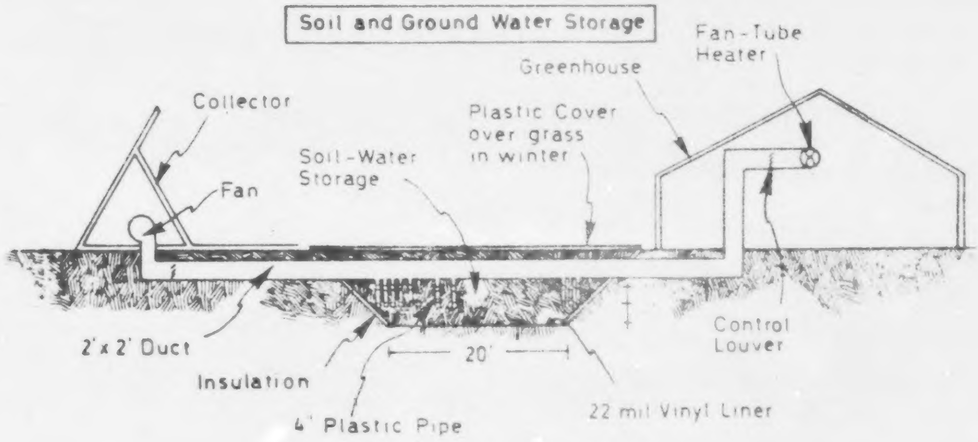
A 2 feet square duct is connected from the 4 inch pipes to the collector and return. The duct can be extended onto the greenhouse, but appropriate thermostats and dampers must be installed to prevent short-circuiting of air or loss of stored heat.

Both the Ohio State and Purdue University systems require a substantial investment for excavation, insulation and lining of a deep pit.

Purdue University: Concentrating Solar Collector


2 x 6
Cover with Reflective Aluminum Siding
2 x 6 18' long, space 4' apart
2 x 4, 12' long
South ➔
4" Polystyrene Board
Cover with double layer of Fiberglass panels or Polyethylene film
Line with Blackened Corrugated Metal Siding
For winter heating, tilt the collector so the angle θ is the latitude plus [illegible]
60°
Reflective Aluminum Roofing
2 x 6
1 x 2 x ½" thick exterior Plywood Gusset nailed to both sides
2 x 6
2 x 4 2' on center
4 x 4 Post, buried 4' deep

Soil and Ground Water Storage

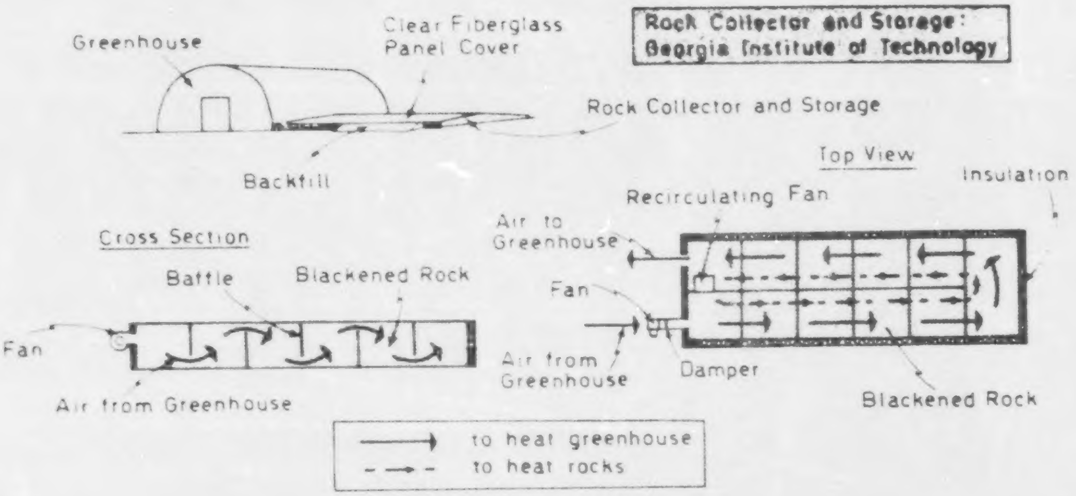

Fan-Tube Heater
Greenhouse
Collector
Plastic Cover over grass in winter
Soil-Water Storage
Fan
2' x 2' Duct
Control Louver
20'
Insulation
22 mil Vinyl Liner
4' Plastic Pipe

Georgia

The Georgia Institute of Technology is testing a 17 feet long bed of large granite rocks painted flat black and covered with 62 square feet of clear fiberglass paneling. The sun warms the rock during the day. Then a fan with a capacity of about 0.3 cfm per square foot of collector recirculates this heat to the cooler region near the bottom. When heat is needed from the storage a larger fan (1.5-2 cfm per square foot of collector surface) warms the greenhouse air by pushing it through the storage.

Tests with 3 to 4 inch diameter and 8 to 12 inch diameter rocks are being made. More study is needed before the optimum size and quantity of rock and the best operating technique can be recommended.

Rock Collector and Storage: Georgia Institute of Technology

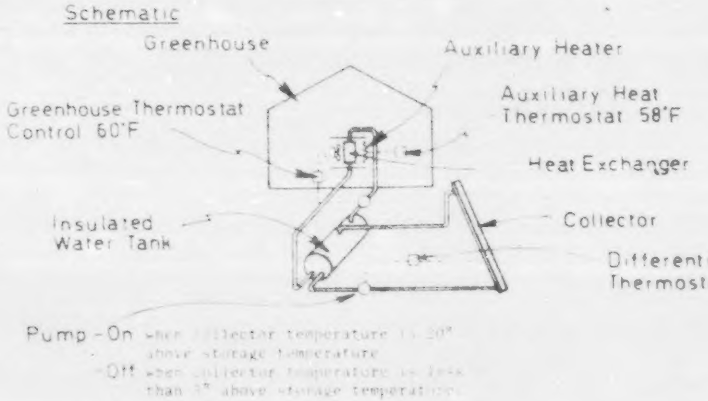

Greenhouse
Clear Fiberglass Panel Cover
Rock Collector and Storage
Backfill
Top View
Insulation
Recirculating Fan
Air to Greenhouse
Cross Section
Baffle
Blackened Rock
Fan
Fan
Air from Greenhouse
Damper
Blackened Rock
Air from Greenhouse
to heat greenhouse
to heat rocks

Alabama

Lockheed Corporation is testing a solar heating system for a 14 ft × 20 ft double polyethylene covered greenhouse at Huntsville, Alabama. Heat from a 200 square foot external collector is stored in a 1,000 gallon insulated concrete water tank. The larger tank replaced two 250 gallon water tanks to obtain longer storage. Controls are simple and the unit has operated with few problems. Approximately 75% of the heat is provided by the solar unit. The large land area required for collection and the cost of storage tanks and collectors must be considered with this type of system.

A large scale demonstration of this type of solar heating equipment is being installed in a commercial greenhouse in Ohio.

Lockheed Solar Heating System


Schematic
Greenhouse
Auxiliary Heater
Auxiliary Heat Thermostat 58°F
Greenhouse Thermostat Control 60°F
Heat Exchanger
Insulated Water Tank
Collector
Differential Thermostat
Pump-On when collector temperature is 20° above storage temperature
-Off when collector temperature is less than 3° above storage temperature

Summary

Many ideas have been presented in this manual as ways to reduce fuel use in greenhouses. Present research suggests these pointers:

Consider energy conservation measures first. Generally the greatest heat losses occur through the greenhouse roof. A modest investment to tighten-up the house, cover with double glazing, or install internal blankets can reduce heat losses 50% or more over conventional glass greenhouses.

Solar heating equipment installed with energy conservation measures has the potential of reducing fuel use by 2/3 or more.

Energy conservation measures allow smaller solar heating systems to be used.

Many of the ideas presented are experimental. Research is continuing to develop systems that will collect the most energy for the least cost. Highly efficient collectors that track the sun and complex chemical storage systems are generally too expensive for the slightly greater energy they collect. Simpler, less expensive devices are needed for the greenhouse.

Few, if any, presently available solar heating systems are cost effective.

Solar heating systems still require maintenance. Because most of this equipment is new, the cost to maintain it is not well known. Some equipment is made with plastics that must be periodically replaced. Other equipment, to reduce cost, is very lightweight and may need replacing in only a few years. Pumps and fans need periodic maintenance. Collectors need occasional cleaning and painting.

Solar heater design is based on average heat loads. Energy collected by a solar heating system is typically stored by heating a large mass of small stones or water. This stored energy slowly dissipates and is lost unless it is called to heat the greenhouse within a day or two.

No solar heater can provide all the heat for the greenhouse. Conventional fuel burning equipment must be built into the system. The very large collector surface and storage volume required for total solar heating is simply too expensive. Particularly in winter, when the most heat is needed, there are too many cloudy days and the sun is too low in the sky to provide enough heat.

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